

JOURNAL OF THE
BOSTON SOCIETY
OF
CIVIL ENGINEERS

OCTOBER, 1926

Featuring

**Observations on
European Water-
Power Practice**

**Improvement of
Boston's Transporta-
tion Facilities**



Vol. XIII

No. 8

BOSTON SOCIETY OF CIVIL ENGINEERS

OFFICERS, 1926-1927

PRESIDENT

CHARLES M. ALLEN

VICE-PRESIDENTS

CHARLES B. BREED

(Term expires March, 1927)

FRANK E. WINSOR

(Term expires March, 1928)

SECRETARY AND LIBRARIAN

JOHN B. BABCOCK, 3d

TREASURER

FRANK O. WHITNEY

DIRECTORS

HENRY S. ADAMS

(Term expires March, 1927)

GEORGE A. SAMPSON

(Term expires March, 1927)

RAYMOND W. COBURN

(Term expires March, 1928)

HARRY E. SAWTELL

(Term expires March, 1928)

PAST PRESIDENTS

(Members of the Board)

FRANK M. GUNBY

EDWIN H. ROGERS

RICHARD K. HALE

SANITARY SECTION

FRANK W. GILCREAS, Chairman

RALPH W. HORNE, Clerk

DESIGNERS SECTION

WALDO F. PIKE, Chairman

SCOTT KEITH, Clerk

NORTHEASTERN UNIVERSITY SECTION

WALDO B. BIRKMAIER, Chairman

LOUIS H. SMITH, Clerk

HIGHWAY SECTION

RAYMOND W. COBURN, Chairman

HAROLD F. MacWILLIAMS, Clerk

Editor — JOHN B. BABCOCK, 3d

715 Tremont Temple, Boston

JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XIII

OCTOBER, 1926

Number 8

CONTENTS

PAPERS AND DISCUSSIONS

	PAGE
Some Observations on European Water-Power Practice. <i>Albert J. R. Houston</i>	329

OF GENERAL INTEREST

Progress on Dorchester Rapid Transit	369
Metropolitan Planning Division Activities	370
Boston & Maine Improves Freight Facilities at Boston	371
Proceedings of the Society:	
Minutes of Meetings	372
Applications for Membership	374
New Members	376
Deaths	376
Book Review	376

Published Monthly, except July and August, by the Society
715 Tremont Temple, Boston, Massachusetts

Subscription Price, \$4.00 a Year (10 Copies)
50 Cents a Copy

Copyright, 1926, by the Boston Society of Civil Engineers.
Entered as second-class matter, January 15, 1914, at the Post Office
at Boston, Mass., under Act of August 24, 1912.

Acceptance for mailing at special rate of postage provided for in
Section 1103, Act of October 3, 1917, authorized on July 16, 1918.

*The Society is not responsible for any statement made or opinion
expressed in its publications.*

BOSTON
WRIGHT & POTTER PRINTING COMPANY
32 DERNE STREET

JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS

Volume XIII

OCTOBER, 1926

Number 8

SOME OBSERVATIONS ON EUROPEAN WATER-POWER PRACTICE

BY ALBERT J. R. HOUSTON *

(Presented September 22, 1926)

I SHALL attempt to indicate some of the features of European water-power practice that came to my attention during three years of study, work and travel in Switzerland, France, Germany and Spain. The data obtained were very freely given; access to the plants and construction sites, as well as employment, was readily obtained.

The subject matter presented is limited in scope, being a record of personal observation rather than a complete description, but it is hoped that a basis will be furnished for an interesting discussion. The sequence of description of the various plants will be from intake to discharge, beginning with the structures for high head plants.

(1) DAMS. — The hydraulic fill dam, although not unknown in Europe, is comparatively rare; and masonry dam practice is not unlike that in the United States. A few years ago probably more dams were built straight, with expansion joints, but a growing tendency seems to exist to curve them in plan. Portland cement concrete is used as a rule, although in France a good deal of slack cement is employed in all kinds of unreinforced concrete. There is a marked tendency, especially where public or semi-public funds are used, to adopt a conservative gravity section. Barberine¹ † and the proposed Grimsel Dam² in Switzerland, and Chevanon³ and the dams on the Rhône in France, are good examples of this. Camarasa,⁴ in Spain, is an example of a very conservative dam, built so by a private company because it was forced on them in order to obtain the approval of public works authorities.

The methods of calculating gravity dams are not very different from those employed here. Mr. Creager's book has been translated

* With Stone & Webster, Inc., Boston, Mass.

† Numbers refer to the bibliography on pages 353 and 354.

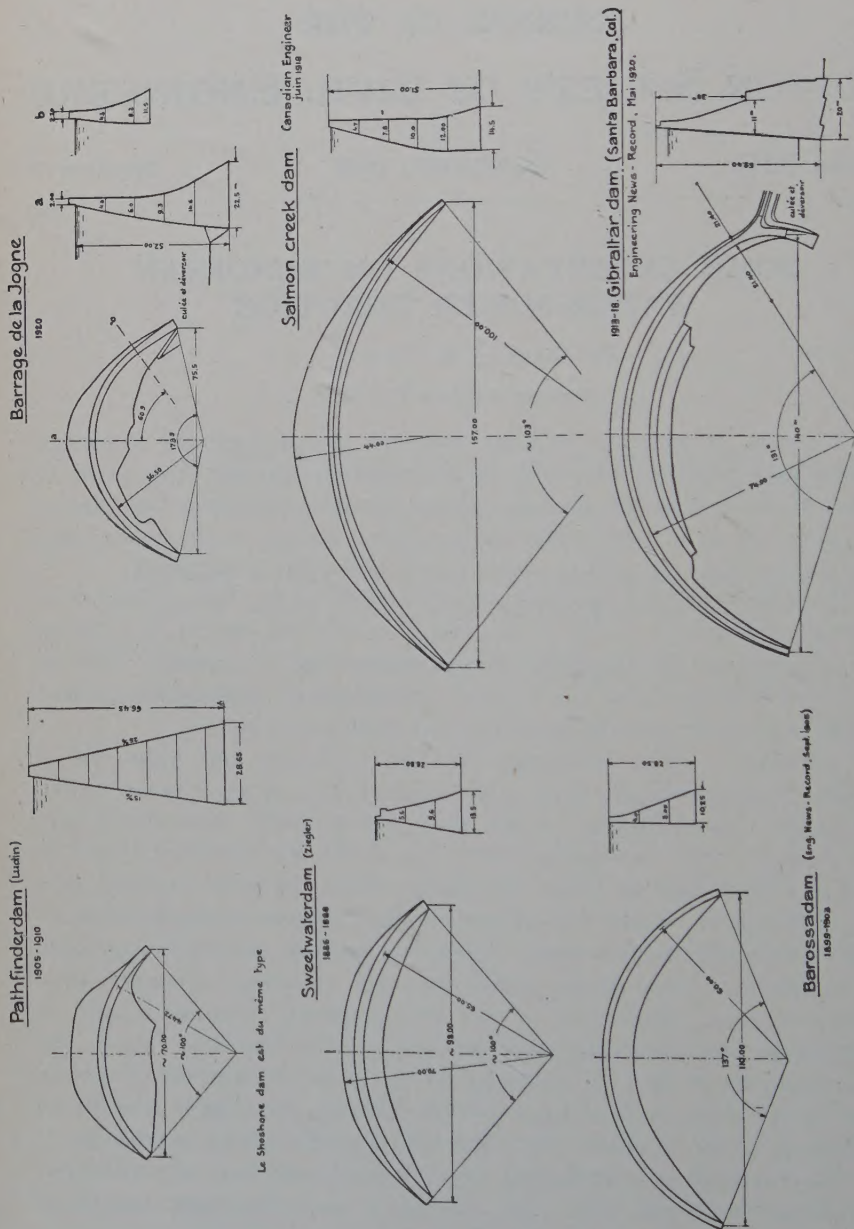


FIG. 1. — ARCH DAM ON THE JOGNE COMPARED WITH SOME AMERICAN DAMS
From: — Stucky "Étude sur les Barrages arqués"

into French and is reported to be considerably used. M. Dégove's study, "Les Grands Barrages en Maçonnerie aux Etats Unis,"⁵ is interesting as representing the reaction of a continental to our methods. Most of the dams in France conform to the precept of M. Maurice Levy, that the compression at the upstream face must at any point be equal to or greater than the pressure of the water at that point. This generally means that the upstream face will have a slight batter.

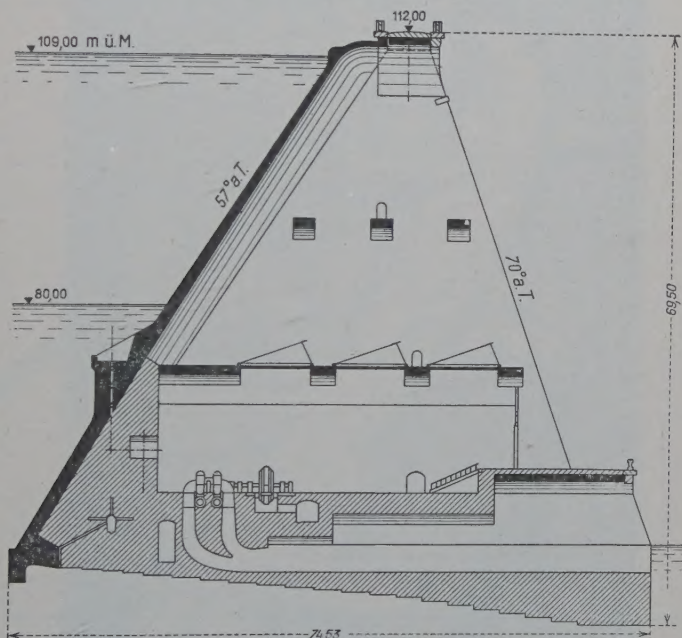


FIG. 2. — TIRSO DAM — SECTION THROUGH ONE OF THE TURBINE ROOMS

From: — Schweizer. Bauzeitung, 1924

However, the site and the government permitting, some very economical arch dams have been built. The one at Montsalvans on the Jogne, for the Broc⁶ plant in Switzerland, and the Montejoque Dam⁷ in Malaga, are two very notable examples. Both were built by Mr. H. E. Gruner of Bâle, and conform to the published theory of his associate, Mr. Stucky.⁸ In the case of the Broc dam, both pyrometer and deflection readings were taken during the setting of the concrete and while the reservoir was filling.

Multiple arch dams are also finding considerable favor, especially in Italy. The new dam just built in Sardinia⁹ is a notable example. The

failure of the Gleno Dam¹⁰ has not greatly jeopardized the popularity of the multiple arch construction, as it is generally agreed that this particular job was both poorly designed and badly executed.

Temporary flashboards that go out in a freshet are an essentially American development and are seldom seen in Europe. Usually some

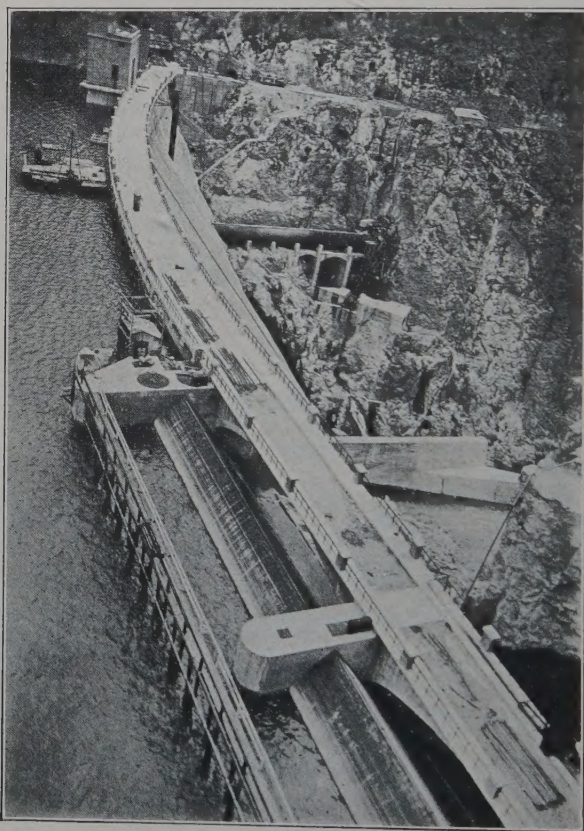


FIG. 3. — FLOATING CONCRETE SECTOR GATE AT
CAMARASA, SPAIN

From: — *Ingeniería y Construcción*, January, 1926

sort of gate is used. The siphon spillway is said to be an Italian invention and its popularity is increasing. Wäggital¹¹ is an example of a new installation. There are a great many so-called automatic gates¹² in use. The experience at Broc, Mühleberg, Tremp,¹³ and Camarasa would seem to indicate that the automatic feature is seldom employed.

Probably one reason for this is that after a plant has been established for some time, the characteristics of the watershed become pretty well known, and it is often advantageous to move the gates before the reservoir level actually begins to change. But at any rate, the ease with which these gates may be operated constitutes a distinct advantage. One of the newest and most interesting of this type of gate is that installed at the Camarasa¹⁴ plant of the Barcelona Light, Power and

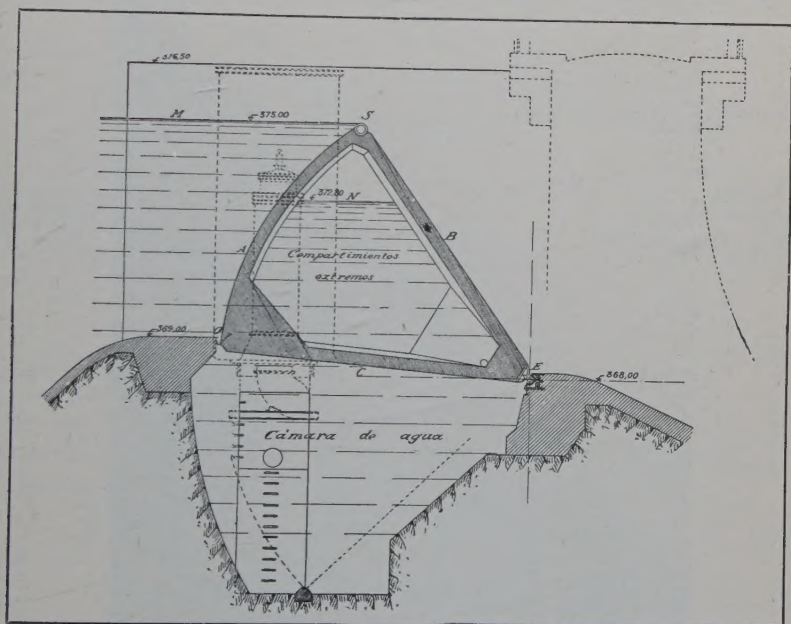


FIG. 4. — FLOATING CONCRETE SECTOR GATE AT CAMARASA, SPAIN

From: — Ingeniería y Construcción, January, 1926

Traction Company, by Stauwehr, A.G., of Zurich. The gates are of the sector type, built of reinforced concrete, and float. Because the hinge is continuous, the water thrust is distributed over the entire spillway and the gates may be made quite long, which reduces the number of abutments and consequently the necessary length of the spillway.

The methods of placing the concrete in dams are usually not radically different from those in this country, although in Germany concrete is more often placed by aerial cableways than with towers and chutes. In Switzerland and France both methods are usually used together.

In the Alps, material is often brought long distances by aerial cableway, the Barberine¹⁵ job being a good example of this.

(2) SILT REMOVAL BASINS. — Glacier water is almost always dirty, because of the rubbing of the glacier against the mountain as it slowly

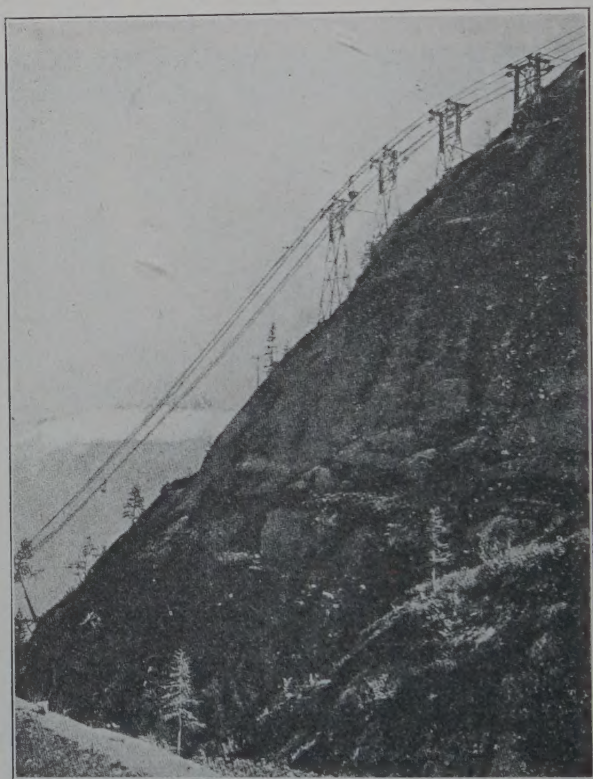


FIG. 5. — AERIAL CABLEWAY FOR TRANSPORTING MATERIAL TO BARBERINE DAM

From: — Schweizer. Bauzeitung, 1923

moves. This grit constitutes a serious peril to long turbine life, and consequently there have been developed a number of devices for removing the material in suspension from the water. This usually takes the form of an arrangement to reduce the velocity evenly across the entire section of flow, after which baffles force the water downwards and then upwards. The inertia of the particles takes them to the bottom. The installations developed by Mr. Büchi¹⁶ of Zurich and by

Mr. Dufour¹⁷ of Lausanne may be mentioned as being very highly perfected.

(3) TUNNELS. — Hand mucking is the rule in most power tunnels, which, in European practice, are seldom of very large bore. This is considered more economical than machine mucking because of the low cost of labor. In Switzerland, where wages are perhaps higher than anywhere else in Europe, a good hard rock miner gets about twenty

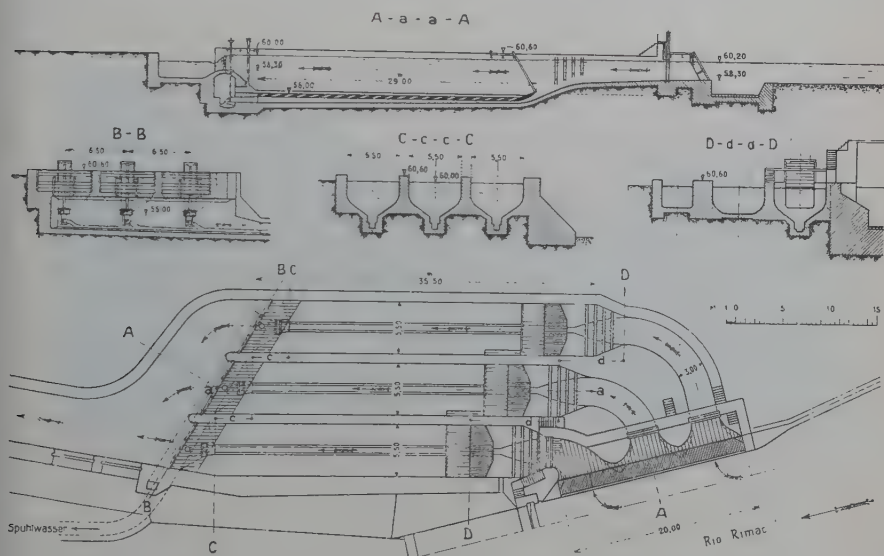


FIG. 6.—DUFOUR TYPE SILT REMOVAL BASIN

Yanacoto Plant on the Rio Rimac in Peru—Capacity, 700 cubic feet per second

From: — Schweizer. Bauzeitung, 1924

cents an hour. Consequently, with hand work, it is desirable to have the mucking go on continuously. Therefore, hand drills are also used in order that the miners may start in on top of the muck pile. Four to five yards a day in a medium-sized two-drill heading constitutes good progress. Many of the early Alpine tunnels were built with the Flottman, a German drill. The Atlas, from Stockholm, is the air drill at present most in favor there, — apparently largely because of its low price. I-R jack-hammers are very popular in France and Spain. The Tunnel du Rove¹⁸ of the Rhône Canal at Marseilles was an exception to general practice, being a very large bore tunnel where machine mucking and many modern refinements were used.

Pressure tunnels are being more generally and heavily lined than formerly. The leakage from the Ritom tunnel has prompted the Swiss Federal Railways to make some rather extensive tests.¹⁹ Parts of various tunnels were blocked off, water pumped in under pressure, and expansion readings taken. The general interpretation of the results seems to be that when a tunnel is to be lined at all, enough reinforcing should be used to take care of all the pressure, — also that grouting behind the lining should be thoroughly and carefully done. The Illsee-Turtmann²⁰ development is an example of a tunnel in which a pipe line has been

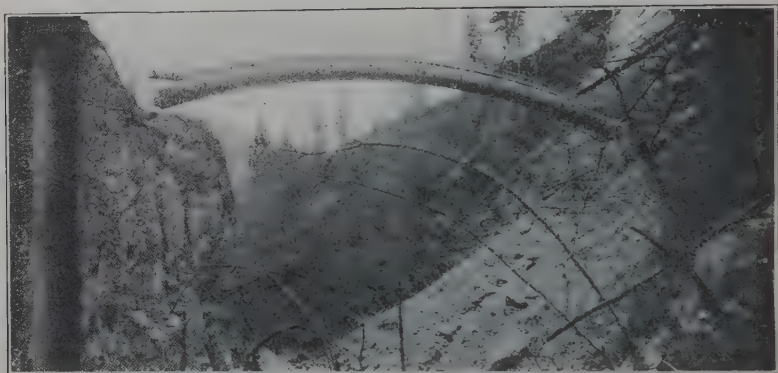


FIG. 7. — PENSTOCK ARCHED ACROSS THE GORGE OF THE VEYTON (ISERE), FRANCE

placed. Such an expedient is of course practical only when small quantities of water are involved, as is the case there.

(4) SURGE TANKS. — The differential principle is little known, although Mr. Gruner has built a couple of tanks in Austria whose action is really similar to that of the Johnson.²¹ Some companies have demanded such close regulation with a sudden increase in load that a number of chambers have been built to act somewhat like the steam-chest of a steam turbine. These surge tanks have large chambers, at an elevation between the top of the penstock and the hydraulic gradient, which supply the water for an increase in load.²² For the calculation of surge chambers, the Prásil formula²³ seems to be one of the most used. There have also been published various graphical methods.²⁴

(5) PENSTOCKS. — The writer did not notice any very great differences between European and American penstock practice. A great deal of welded and some banded pipe is used. One continental manufacturer of the latter product has recently had considerable success

in this country.²⁵ One or two cases where a pipe line had to cross a canyon and was arched to support its own weight may be mentioned as interesting novelties. It does not seem to be thought so essential to have a penstock for each unit — manifolds being more generally the rule than here.

(6) VALVES. — A great many butterfly valves are used. A number of firms are also making some sort of balanced valve similar to the Johnson or those developed by our own Reclamation Service. Among these may be listed: The English Electric Company, Schneider, Neyret-Beylier & Piccard-Pictet, Constructions Électriques de France, and von Roll. The Escher Wyss rotary valve has had considerable success and

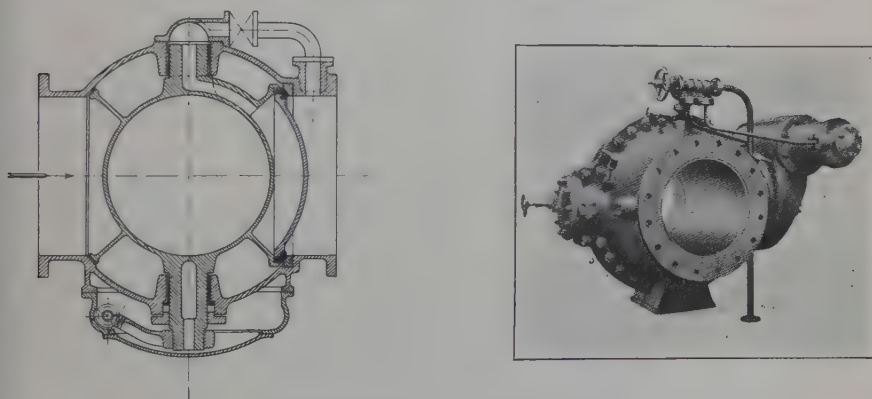


FIG. 8. — ESCHER WYSS ROTARY PENSTOCK VALVE

Left — Section showing valve closed

Right — View showing valve open

Courtesy of Mr. Charles C. Egbert, Niagara Falls, N. Y.

is rather interesting. It is somewhat like a petcock in that a short section of the pipe rotates on a horizontal axis. Tightness is secured by hydraulic pressure from the penstock, which forces a circular cover over the downstream opening of the penstock. It is usually used only as a penstock valve or in places where it will always be either wide open or completely closed. Neyret-Beylier & Piccard-Pictet²⁶ have recently started the manufacture of a valve similar, except that tightness is secured by rotating the valve on an eccentric axis.

(7) PELTON WHEELS. — The Pelton wheel, properly speaking, came from America to Europe, and has been very intensively developed there. With the aid of several well-equipped laboratories which have been in existence a number of years, it has been brought to the point of

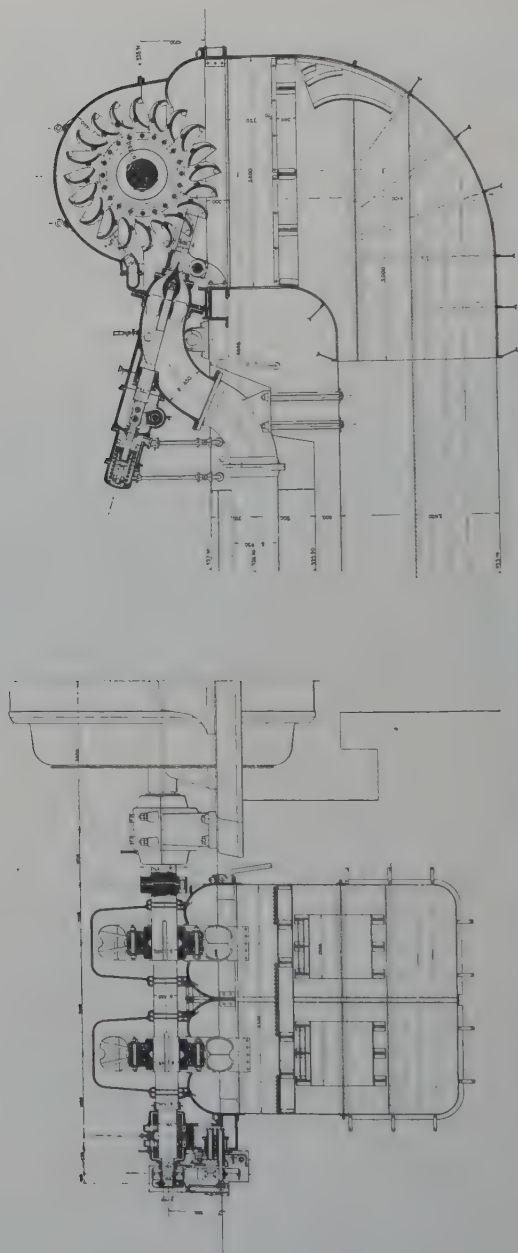


FIG. 9. — DOUBLE PELTON WHEEL FOR THE AMSTEG PLANT OF THE SWISS FEDERAL RAILWAYS
14,300 h.p., 333 $\frac{1}{3}$ r.p.m., head 905 ft.

From: — Bulletin Technique de la Suisse Romande, 1923

giving very high efficiencies — even under part loads. The impulse wheel seems to be preferred for power for traction work, when there is a choice,²⁷ because of this high part load efficiency and because of ease of governing.

The writer has never seen a double-overhung job in Europe. When multiple wheels are used apparently they are always placed side by side. In one case — Schwarzenbach²⁸ in the German Black Forest — three wheels with two nozzles apiece are used. A number of vertical shaft installations have also been built. The Fully²⁹ plant is the classic example

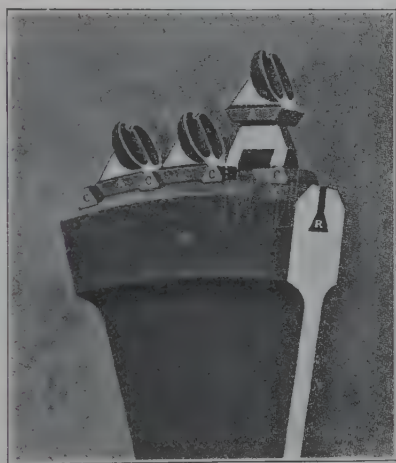


FIG. 10. — WHEEL FOR THE FULLY PLANT

Showing method of attaching the buckets
— 500 r.p.m., diam. 12.2 ft. (about)

of a very high head installation. The head is about 5,400 feet and the wheels were designed to run at a little more than $0.50 \sqrt{2gh}$ instead of a little less, in order to reduce the runaway speed.

In larger wheels, where the buckets are cast separately, it seems customary to fit a key between each bucket so that the thrust will be distributed over the entire ring. Sometimes the buckets are fastened on with rings shrunk over the shoulders on both sides. At least one firm is using taper bolts. Speeds seem to run a little higher than is customary with us. The Lac d'Oô plant in the Pyrenees runs at a speed of 1,500 r.p.m.³⁰

The standard form of regulation is a combined needle nozzle and deflector. The deflector diverts the jet or a portion of it from the wheel, while the needle closes slowly. Auxiliary overspeed safety devices are also often installed. The Seewer³¹ regulating device consists of vanes which project into the nozzle and change the jet into a spray. The turbines built by the English Electric Company for the Tata plant near Bombay are so equipped.

(8) LOW HEAD DAMS. — Some cylindrical gates, some sector gates, and a few of the automatic gates³² above mentioned have been installed. But the double or triple stony roller gates are much more common in low head developments. They are usually operated from above rather than from below, as at Gatun, for instance. All kinds of expedients have been adopted to prevent erosion just below the toe of the dam. Often the apron is very long. Sometimes the hydraulic jump is used to build up a reverse eddy which should pile the material up at the end of the dam, rather than cut it away. At Mühleberg³³ "chicanes" are used, as at Gatun.

(9) RACKS. — An interesting development is the self-cleaning turbine rack. The entrance space is divided vertically into two or more sections and one can be closed off at a time, inducing a reverse flow through the rack on the closed side, and carrying off any rubbish that may be piled against it. Augst-Wylan³⁴ on the Rhine was one of the first of these installations, and Chancy-Pougny³⁵ on the Rhône is one of the newest.

(10) REACTION TURBINES. (*a*) *Francis*. — The Francis type of runner made its appearance in Europe soon after it first began to be used in this country, and was originally called the "American type" of wheel. It has developed there very much along the same lines as here, proceeding from the "cut and try" stage to the development of rational theories which will produce reasonable results, and later going through gradual refinement.

A few details will now be touched upon simply in the order in which they occur to the writer.

There is in Europe but little demand for very large units, and the Kanidera³⁶ turbines for Japan, developing 38,400 h.p. at a head of 440 feet and 300 r.p.m., built by Escher Wyss, probably constitute the record for output. Rubber seal rings are unknown. A number of firms use labyrinth packing, but several prefer to place their reliance in flat deep rings, simply offering a long path of flow to the water. "Necked down" or bored out regulating links, to break if anything gets stuck in the gates, are not common. The turbines built under the

Piccard-Pictet patents by Neyret-Beylier & Piccard-Pictet in Grenoble and by the Atelier des Charmilles in Geneva usually have coil springs interposed in the link mechanism of each guide vane. The turbines built by Riva of Milan have no solid regulating ring. Each wicket gate shaft carries two arms cast in one piece and making equal and opposite angles with a radial through the turbine center line. Adjacent

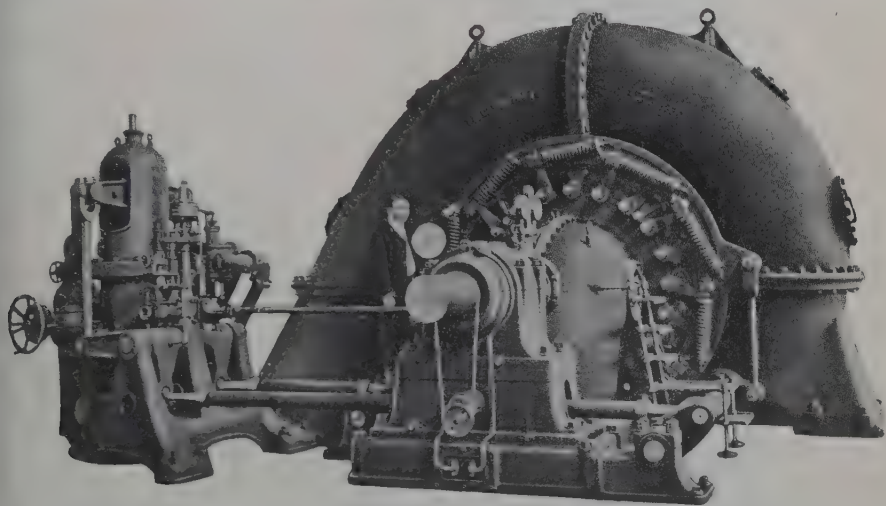


FIG. 11. — TURBINE AT VENTAVON, FRANCE

Showing springs in the gate operating mechanism — Piccard-Pictet patents

From: — Camerer "Wasserkraftmaschinen"

arms are connected, thus forming what is in effect a ring. Wooden guide bearings for vertical shaft units have been built for foreign customers that had American purchasing engineers. Metal bearings, however, are standard in Europe. Speeds probably run a little higher there than here, 600 r.p.m. being not at all uncommon. Most of the thrust bearings are based on the Reynolds theory, with shoes which either tilt, deflect, or have a constant planed angle.

(b) *High Speed Turbines.* — The units at Chancy-Pougny³⁷ probably constitute the record for size. They pass 3,250 cubic feet per second. The head varies from 20.7 to 28.6 feet and the outside runner diameter is 17 ft. 7 in. These units are of the high-speed Francis type. There has also been a great deal of development in the way of axial and diagonal flow wheels. The Atelier des Charmilles is building a so-called conical turbine.³⁸ The wheel is of the high-speed Francis type

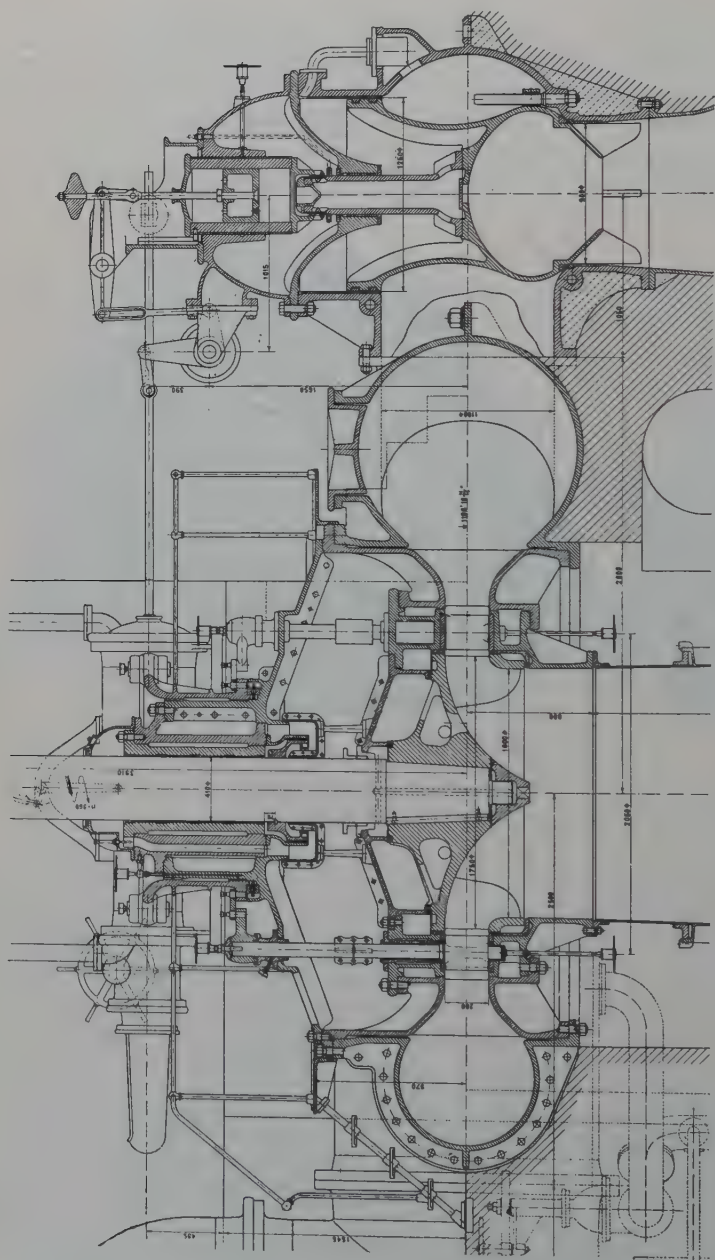


FIG. 12. — SECTION THROUGH TURBINE AND PRESSURE REGULATOR

Yomikaki Plant, Japan. — 22,000 h.p., 360 r.p.m., head 370 ft. For section through plant see Fig. 17.

From: — Schweizer. Bauzeitung, May 10, 1924

and the wicket gates form a frustrum of a cone. This arrangement has been particularly successful in enabling larger units to be installed when rebuilding an antiquated plant. The Bell³⁹ turbine, which is of the screw type and really runs in the draft tube, is well known in this country, as it is being offered to the public by S. Morgan Smith. Escher Wyss is also building a similar turbine as well as the Kaplan⁴⁰ propeller wheel. All of the member firms of the Kaplan concern are making this type of wheel with either fixed or movable blades. The Lawczek⁴¹

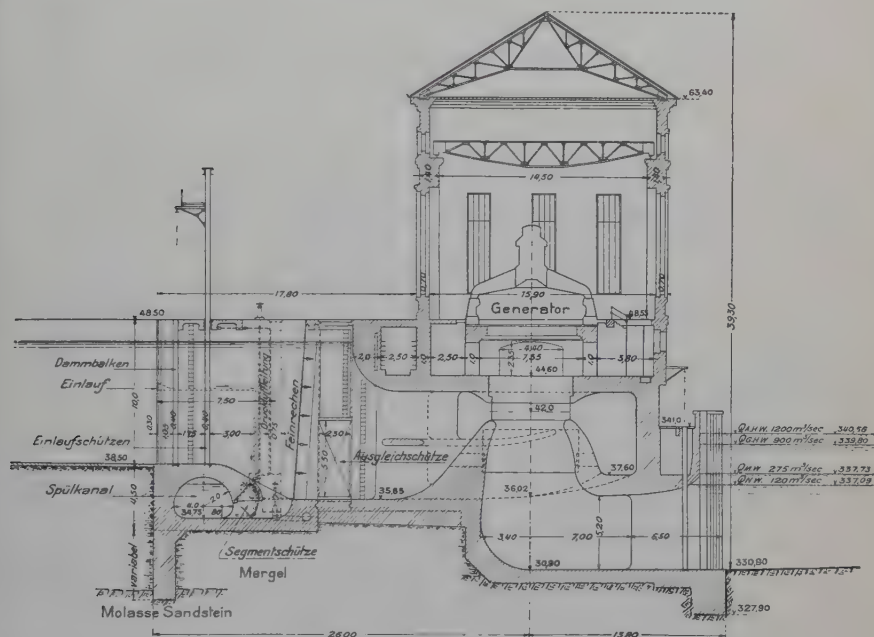


FIG. 13. — SECTION THROUGH CHANCY-POUGNY PLANT

Courtesy of Mr. H. E. Gruner, Bâle, Switzerland

turbine gives high specific speeds and a reasonable efficiency at the point of best efficiency, but the curve is rather peaked. However, it is cheap to build and lends itself readily to the manufacture of large size units. Professor Lawczek believes that some such units could profitably be installed in run of river plants to develop secondary power. When there is enough water to run them at all, they could always be run at best efficiency, and the plant regulation could be handled by the Francis or Kaplan units, which have a flatter curve. This is apparently the plan for Lila Edet.⁴² In Munich the experiment has been tried of

having several low head wheels drive pumps in series, producing high-pressure water to drive a Pelton wheel. A number of plants have also been built in Germany with vertical shaft turbines driving vertical shaft offset generators through herringbone gears.⁴³ The cost of the gearing, additional power-house superstructure, and capitalized value of the power losses was more than balanced by the saving in generator costs. The general feeling would seem to be that the problem of the axial flow turbine is not one of high speed itself, but rather one of erosion and of the efficiency that can profitably be sacrificed to high speed.

A few plants have also been built with the Hallinger⁴⁴ disposition. The horizontal shaft wheels are placed in a housing within the power

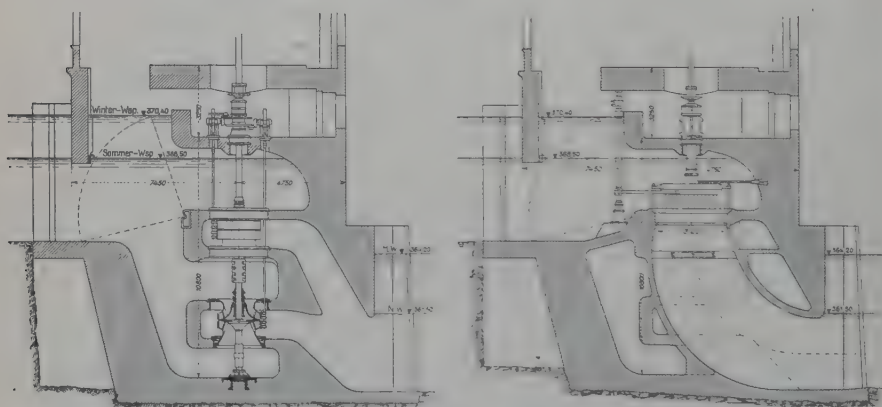


FIG. 14. — REPLACEMENT OF OLD UNITS AT CHÈVRES PLANT, SWITZERLAND

Left — Old unit Right — New unit

From: — Schweizer. Bauzeitung, Aug. 25, 1923

house itself, the top of which is placed slightly above ordinary head-water level. The housing is kept full by siphon action. Among the advantages claimed are low foundation costs and accessibility.

(c) *Draft Tubes*. — Several firms (Escher Wyss, for instance) have been using the Prášil tube for a number of years.⁴⁵ This tube is based on the theory that the mean velocity across a plane perpendicular to the flow should vary in inverse proportion to the height of the plane above the floor of the tail race. Any one who cares to plot up such a curve can readily demonstrate the degree to which this condition is fulfilled in the modern American spreading type of tubes, although, of course, Professor Prášil had published his dissertation⁴⁶ many years before these devices were ever heard of.

The Bell Company uses an elbow tube with a very long horizontal part. The discharge losses from the Bell helical turbine are said to run as high as 60 per cent, so the tube must regain very effectively, as their published overall efficiencies are rather good. Kaplan also recommends

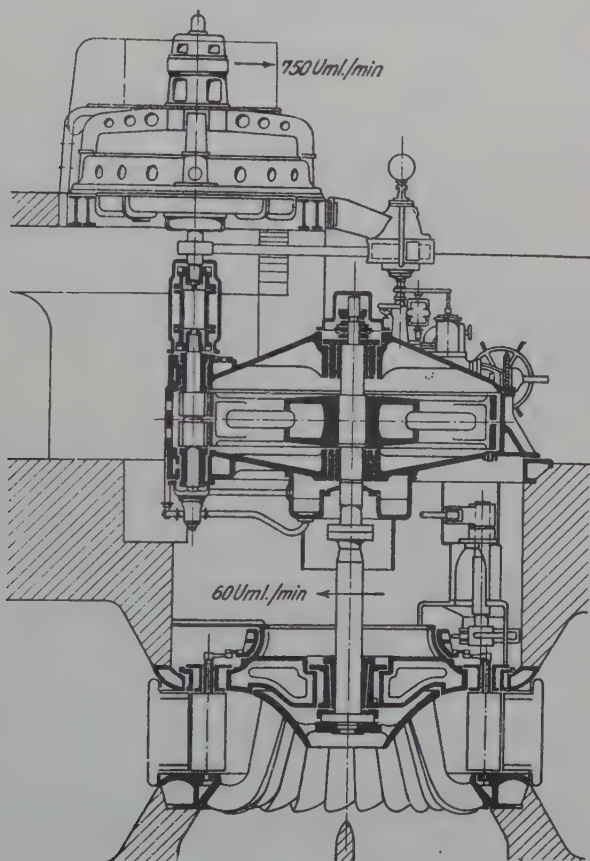


FIG. 15. — GEAR DRIVE UNIT AT HOHENSTEIN ON THE RUHR

1,250 h.p., 60/750 r.p.m., head 14.1 ft.

From: — Zeit. Vereines deutscher Ingenieure, April 12, 1924

an elbow tube. There is no flare to the vertical portion, all the regain being accomplished after the bend is passed.

(11) ARCHITECTURE. — Generally speaking, a great deal more attention is paid to the appearance of the power house itself in Europe

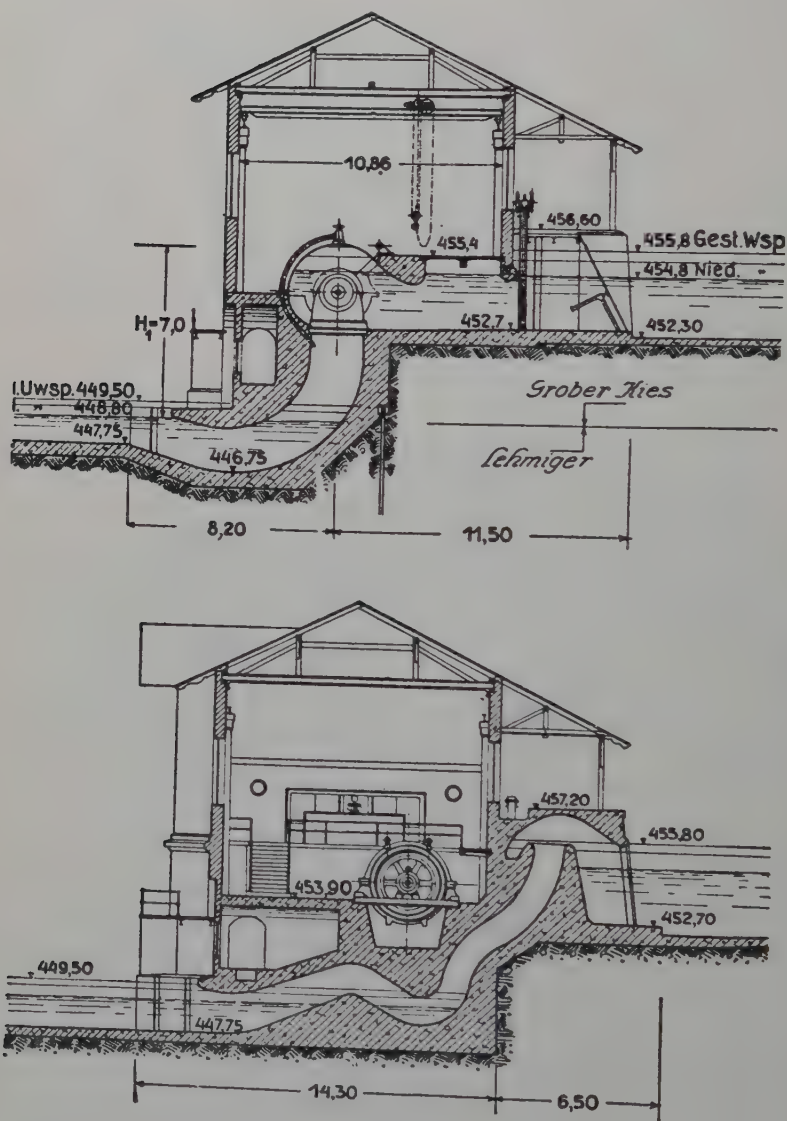


FIG. 16. — HALLINGER TYPE OF SETTING
 From: — Zeit. Vereines deutscher Ingenieure. Feb. 9, 1924

than is general in America. This applies to the interior as well as to the exterior. The theory, of course, is that the personnel will take better care of the equipment, and that the public will lend its support more readily to the enterprise. One of the most notable examples and one of the marked exceptions to this tendency observed by the writer were

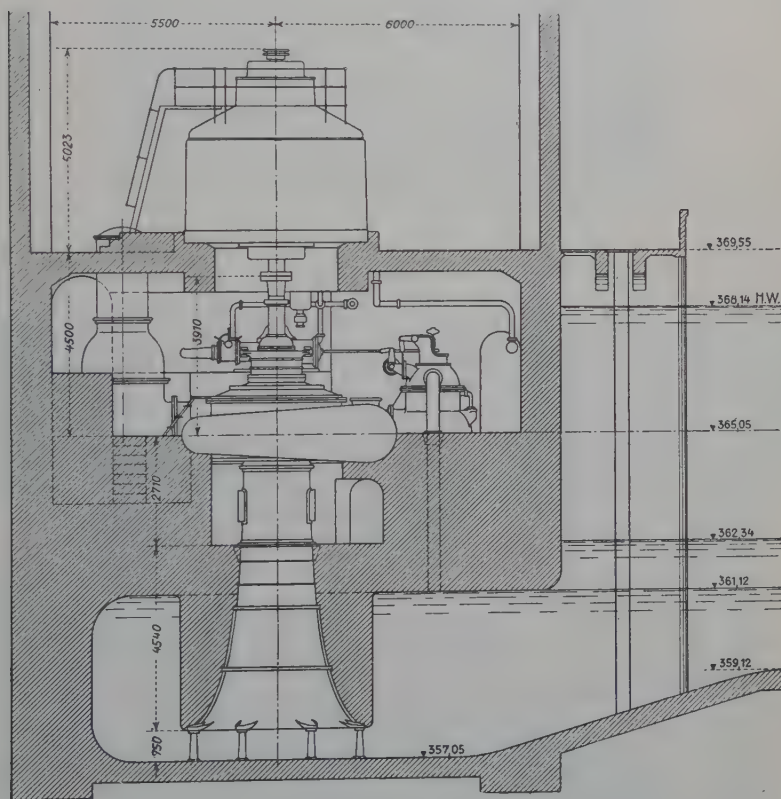


FIG. 17. — SECTION THROUGH YOMIKAKI PLANT

Showing "Prášil" type draft tube. For section through wheel see Fig. 12

both encountered in Spain. The plants of the Barcelona Company are mostly very plain, and the newest, Camarasa,⁴⁷ is as box-like a rough concrete structure as could be found in this country. They make a particular point of explaining to visitors that, while they have the very best of equipment, none of the customers' money is going to pay for frills. At the other extreme, the Unión Eléctrica Madrileña, at their



FIG. 18. — INNWERK, BAVARIA, GERMANY

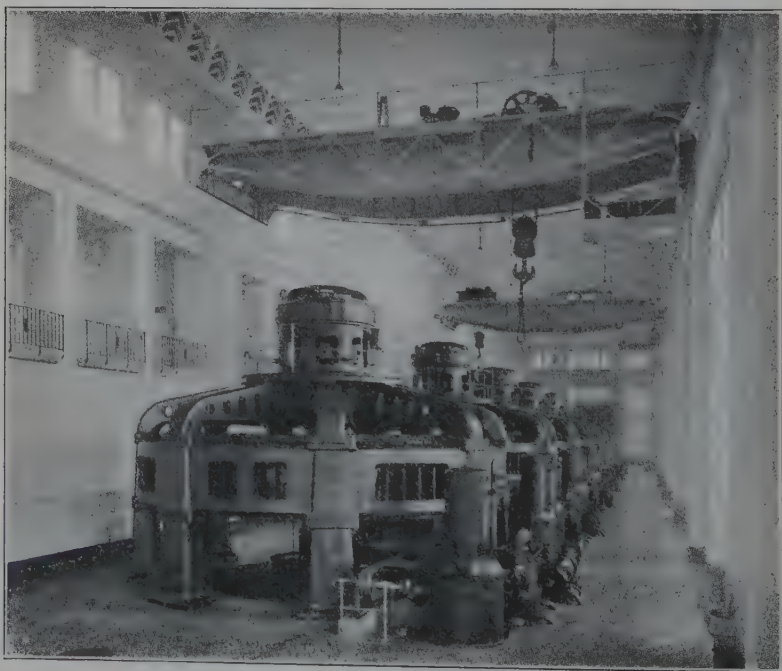


FIG. 19. — INTERIOR OF OLTEN-GÖSGEN PLANT, SWITZERLAND

From: — Schweizer. Bauzeitung, 1920

Villalba⁴⁸ plant, have, in addition to a very nice power house, built attractive cottages for the employees and even a beautiful chapel.

(12) INTERCONNECTION. — Interconnection is going forward at almost as rapid a pace as here. Most of the Swiss power systems are tied together through one of the two "buss-line companies," Schweizerische Kraftübertragung, A.G., and Energie de l'Ouest Suisse, S.A. The Swiss also have a number of ties with the distributing systems of Baden, Alsace, and Northern Italy. France is also making rapid progress with interconnection, and is trying to co-ordinate the problem as much as possible with that of railway electrification.⁴⁹ Eguzon⁵⁰ and the plants



FIG. 20. — AUGST-WYHLEN PLANT ON THE RHEIN
 Left end — German steam and hydro-electric plants
 Right end — Swiss hydro-electric plant and ship lock
 From: — Schweizer. Bauzeitung, 1914

being built in the Massif Central⁵¹ for the Paris-Orleans railway will work in parallel with the steam stations of the Union d'Électricité, in the Paris region.

The advantages of connecting plants that have no storage with some that have is keenly realized, and has led to several installations where energy is stored by pumping water. The surplus power developed by the low head plants is used to pump water into the storage reservoir of a high head plant. Sometimes the water is pumped from a pond intermediate in elevation between the reservoir and its power house. In such cases the water, when used to develop power, will fall through a higher head than against which it was pumped. The Murgwerke,⁵² Wäggital,⁵³ and Illsee-Turtmann⁵⁴ are three very modern examples of power plants with pumping installations.

(13) GOVERNMENT OWNERSHIP. — As in this country, everything exists from purely government to purely private ownership. One rather interesting type of set-up, however, is a regularly incorporated company, a majority of the voting stock of which is held by the government, or jointly by several local governments. Most of the larger Swiss and a number of the German hydro-electric concerns are of this type. The system seems to operate pretty well so far as keeping politics out of business is concerned, and also assures a relatively low rate of interest on borrowed capital. It is, nevertheless, an open question as to whether the incentive to economy is as great as in a purely private undertaking.

A FEW EXAMPLES OF EUROPEAN AND AMERICAN PRACTICE WITH REGARD TO CHOICE OF TYPE OF WHEEL FOR MEDIUM HIGH HEADS

PLANT	Output (h.p.)	Specific Speed	Speed (r.p.m.)	Head (feet)	Type	Date	Mfg.
(a) Handeck	4 x 25,000	7.6	500	1,640	Vertical shaft Pelton — 4 nozzles.	Projected	E. W. C. ⁵⁵ *
(b) Big Creek II	2 x 20,000	4.9	375	1,680	Pelton horizontal shaft — double overhung.	1912-13	Allis-Chalmers ⁵⁶
(c) Moccasin Creek	4 x 25,000	5.5	257	1,250	Pelton horizontal shaft — double overhung.	1925	P. W. W. ⁵⁷
(d) Necaxa	6 x 8,000	4.0	300	1,200	Vertical shaft Pelton — 2 nozzles.	1906	E. W. C. ⁵⁸
(e) Murgwerke	2 x 25,800	11.75	500	1,170	Horizontal shaft Pelton — 3 wheels, 6 nozzles.	1924	E. W. C. & Voith. ⁵⁹
(f) Caribou	3 x 30,000	4.8	171.4	1,008	Horizontal shaft — double overhung Pelton.	1919-21	Allis-Chalmers ⁶⁰
(g) Oak Grove	1 x 35,000	19.6	514	900	Francis vertical shaft.	1924	P. W. W. ⁶¹
(h) Biaschina	3 x 10,000	6.5	300	853	Vertical shaft Pelton — 4 nozzles.	1907	E. W. C. ⁶²
Biaschina	1 x 15,000	—	—	—	Vertical shaft Pelton — 4 nozzles.	1911	E. W. C.
(i) Kern River III	2 x 22,500	17.4	500	810	Vertical shaft Francis.	1921	P. W. W. ⁶³

* Reference in bibliography.

BIBLIOGRAPHY

Abbreviations

S. B. Z. — Schweizerische Bauzeitung
 Z. V. d. I. — Zeitschrift des Vereines deutscher Ingenieure
 R. — Available as reprint

1. S. B. Z., 1919, p. 256.
2. S. B. Z., Jan. 10 & 17, 1925; Génie Civil, Mar. 21, 1925.
3. La Houille Blanche, Nov.-Dec., 1922, & Jan.-Feb., 1923.
4. Engineering News-Record, Aug. 17, 1922.
5. Librairie de l'Enseignement Technique, rue Thénard, Paris.
6. Bul. Tech. de la Suisse Romande, 1922, pp. 1, 25, 49, 85, 99.
7. S. B. Z., Mar. 28, 1925; Génie Civil, Dec. 13, 1924; Engineering News-Record, July 24, 1924.
8. "Etude sur les Barrages arqués" par Alfred Stucky. Librairie Rouge, Lausanne.
9. Engineering, Nov. 7, 1924; Elec. Review, June 6, 1924.
10. S. B. Z., Feb. 9 & 16, 1924; La Houille Blanche, Mar.-April, 1923.
11. S. B. Z., Feb. 19, 1921; Power, May 5, 1925.
12. Energia Eléctrica, Sept. 10 & 25, Oct. 10, 1922; Revue Industrielle, Sept. & Oct. 1922.
13. Génie Civil, May 31, 1919.
14. Ingenieria y Construcción, Jan., 1926.
15. S. B. Z., 1923, R.
16. S. B. Z., June 23, 1917; Schw. Wasserwirtschaft, June 10 & 25, 1920.
17. S. B. Z., Apr. 12 & 26, 1924; S. B. Z., 1926, p. 175.
18. Annals du Ponts et Chaussées, March-April, 1923; The Engineer, June 4, 1926.
19. S. B. Z., Jan. 5, 1924; Z. V. d. I., April 12, 1924.
20. S. B. Z., Vol. 84, No. 24.
21. For example, Partenstein — Z. V. d. I., Nov. 28, 1925.
22. Examples: Partenstein (see above) and Lac d'Oô—Huguenin in S. B. Z., 1919. R.
23. S. B. Z., 1908 & 1922. R.
24. Examples: L. Mühlhofer—"Zeichnerische Bestimmung der Spiegelbewegungen in Wasserschlossern" Springer, Berlin, 1924; A. Schoklitch "Graphische Hydraulik," Teubner, Leipzig, 1923.
25. For theoretical discussion, see Engineering, Oct. 12, 1923.
26. Gariel, "Rapport sur les accessoires de turbines hydrauliques," 3^e Congres de la Houille Blanche, Grenoble, 1925.
27. For example at Walchensee — Die Wasserkraft May 15, 1924.
28. S. B. Z., 1923, Nos. 3 & 4; Die Wasserkraft, Jan. 20, 1924.
29. Bul. Tech. de la Suisse Romande, 1916, Nos. 1 & 7.
30. See (22).
31. English Electric Journal, April, 1924.
32. See (12), (13), & (14).
33. S. B. Z., 1918, No. 8.
34. S. B. Z., 1913-1914. R.
35. Revue Générale de l'Électricité, July 12, 1924. R.
36. Elektrotech. Zeit., April 2, 1925.

37. Sec (35).
38. S. B. Z., Aug. 25, 1923.
39. S. B. Z., 1924, Nos. 1, 2, 3, & 4. R.
40. Z. V. d. I., 1921, Nos. 40 & 41, 1923, No. 18; 1st World Power Conference, London, paper No. 64.
41. 1st World Power Conference, London, paper No. 101.
42. Z. V. d. I., April 12, 1924; Eng. Jl., Aug., 1925.
43. Z. V. d. I., July 22, 1922; S. B. Z., Nov. 11, 1922.
44. Z. V. d. I., Feb. 9, 1924.
45. S. B. Z., May 10, 1924.
46. S. B. Z., 1903. R.; Prášil: Tech. Hydrodynamik, Springer, Berlin, 1913, pp. 180-209.
47. Engineering News-Record, Aug. 17, 1922.
48. Revista de Obras Publicas, Nov. 15, 1925.
49. Engineering, Feb. 26, 1926; Pacoret — "L'Électrification de la France" Librairie de la Vie; Technique et Industrielle, 14 rue Segnier, Paris.
50. La Nature, July 3, 1926; Revue Industrielle, Jan., Mar., May, & June, 1924.
51. Engineering, Feb. 26, 1926; La Houille Blanche, Nov.-Dec., 1922, & Jan.-Feb., 1923.
52. S. B. Z., Vol. 82, Nos. 3 & 4; Die Wasserkraft, Jan. 20, 1924; Z. V. d. I., May 5, 1923.
53. S. B. Z., Feb. 19, 1921; Power, May 5, 1925.
54. S. B. Z., Vol. 84, No. 24.
55. S. B. Z., Jan. 10 & 17, 1925; Génie Civil, Mar. 21, 1925.
56. Stone & Webster Journal, Vol. 13, p. 236; U. S. G. S. Water Supply Paper No. 493.
57. General Electric Review, Feb., 1924; Power Plant Engineering, May 15, 1923; Jl. of Elec. and Western Industries, Nov. 15, 1918, & Jan. 15, 1919.
58. Proceedings, American Society of Civil Engineers, Oct., 1906; Engineering Record, June 9, 1906.
59. Z. V. d. I., May 5, 1923; S. B. Z., July 21 & 28, 1923; Die Wasserkraft, Jan. 20, 1924.
60. Journal of Elec. & Western Industries, Dec. 15, 1921; Power, Dec. 13, 1921; Stone & Webster Journal, Vol. 27, p. 260.
61. Mechanical Engineering, June, 1925; Power, June 2, 1923.
62. Bul. Tech. de la Suisse Romande, 1911, p. 216; Zeit. f. d. ges. Turbinenwesen, 1913, Nos. 1-4; Camerer — "Wasserkraft Maschinen," Engelmann, Leipzig, 1924, Plate 38.
63. Mechanical Engineering, April, 1922; Power, June 21, 1921; Engineering News-Record, Sept. 15, 1921.

Discussion

PROF. CHARLES M. ALLEN:* I am going to ask Mr. Houston what he found in the way of research laboratories abroad? How did Pelton wheel efficiency there compare with that in this country?

MR. HOUSTON: I don't like to talk about efficiencies as I have no exact figures. The question of measurement of quantity, head, and output makes it a hard subject to discuss. It would be natural to

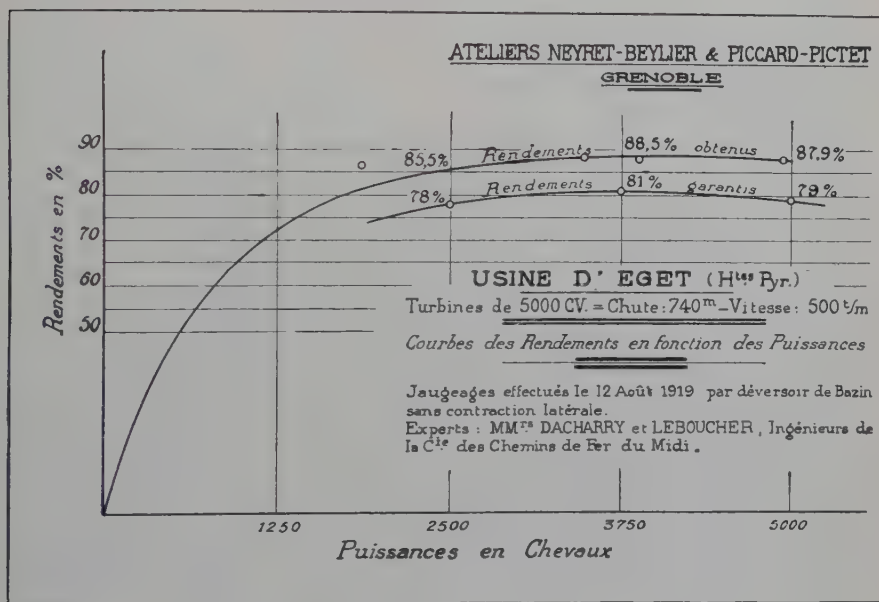


FIG. 22. — EFFICIENCY CURVE OF PELTON WHEEL
Eget Plant in the French Pyrenees

From: — *Revue Générale de l'Electricité*, July, 1920

expect that Pelton efficiencies run a little higher there than here, as they seem to have done more thorough and systematic research on them than we have. I believe that they consider about 87 per cent pretty good for medium sized units. They have some well-equipped laboratories, several of which have been in operation for a number of years.

The trend in Europe is toward larger units, as it is here. Not long ago 10,000 h.p. was considered pretty big. Now 20,000 and 30,000

* Professor of Hydraulic Engineering, Worcester Polytechnic Institute, Worcester, Mass.; President, Boston Society of Civil Engineers.

h.p. units are becoming the rule rather than the exception. When the head is sufficient and plenty of water is available, the tendency is naturally toward larger units and fewer in number in the power house, just as it is in this country.

So far as "automatic" control is concerned, I believe there is very little of this going on in Europe. I have heard about something along this line being done in Scandinavia, but I don't know anything about it. I never happened to see an automatically controlled plant on the Continent. I don't know whether there are any in existence. The reason may be that labor costs less there than here. But there are other advantages to automatic control, so they may be expected to gradually put it into use.

QUESTION: I should like to ask Mr. Houston what he knows about the location of transformers in European stations — whether they are outside or inside?

MR. HOUSTON: There have been several outside transformer stations, and I believe they have been operating with considerable success. I think that there is a tendency in that direction. There is to be one at the plant of which I showed the slide of the aerial cableway.* That station will be located where they are pretty likely to have a good deal of snow a great part of the year. But they do not anticipate trouble. There are also quite a number of other stations. I think that a tendency in that direction is to be noticed. It is, however, coming much more slowly there than here.

WILLIAM D. HENDERSON:† In Europe there seems to be a wider choice of high-speed water-wheel runners for a given plant than exists in this country. For example: taking three stations which are reasonably comparable we find at the Chancy-Pougny development, which Mr. Houston has referred to, a Francis runner whose specific speed is about 120; at Lilla Edet, Sweden, two types of propeller runners both having specific speed of about 140; while at Kachlet, Germany, a Voith runner with a lower specific speed than the Francis runner at Chancy-Pougny, about 115.

The rated heads at the latter plant and at Kachlet are nearly the same, — 26.7 and 25.1 feet respectively. The wheels at both plants develop about 7,500 h.p., yet one is a Francis runner 18 feet in diameter, and the other a propeller type 15 feet in diameter.

At Lilla Edet the head is 21.3 feet. Both types of turbines installed

* Oberhalsi Development of the Bernese Power Company. The outdoor substation will be at Meiringen (elevation about 2,000 feet). Both transformers and switches will be outside.

† With Jackson & Moreland, Consulting Engineers, Boston, Mass.

there develop a little more power than the two plants just mentioned, approximately 10,000 h.p., and in both the runners are about 19 feet in diameter. One of these types is the Lawaczeck wheel with steeply inclined blades, of which there are two, and the other, of which there is one, is an adjustable blade Kaplan turbine which, as Mr. Houston suggests, is intended to handle plant regulation because of its excellent "part gate" efficiencies.

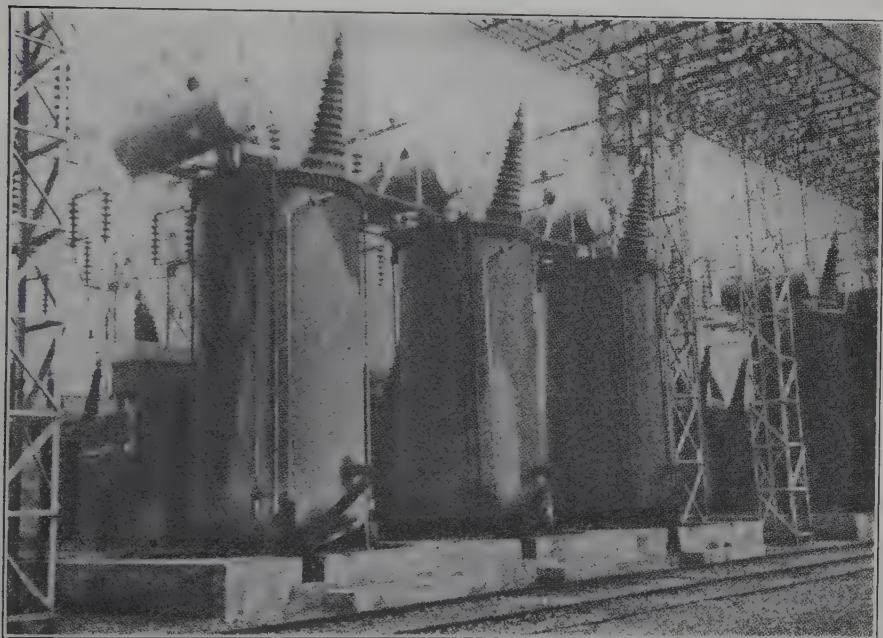


FIG. 23. — OUTDOOR TRANSFORMERS

Basse-Isère Plant in central France — 6000/120,000 volts

From: — La Houille Blanche

In this country manufacturers would no doubt offer a propeller runner for a plant with the characteristics of Chancy-Pougny. I understand that the head there varies somewhat, perhaps from 27 down to 20 feet. However, American manufacturers can give us a propeller wheel with a very flat envelope curve of the maximum efficiencies for each head in the range of 20 to 27 feet, or even a wider range. With an installation, as they have, of five comparatively small units, 7,500 h.p., it would seem that fairly good regulation could be obtained without part

gate operation of any unit. A fixed blade propeller runner would not have as good part gate efficiencies, but certainly under ordinary conditions it would be much cheaper to purchase.

It would be very interesting to know something about the reasons for selecting the Francis runner at Chancy-Pougny. I understand that they were cast in Czecho-Slovakia, and it occurs to me that conditions of European currency at the time they were purchased may have been a factor in their choice. Perhaps Mr. Houston can tell us something about the reasons.

MR. HOUSTON: I don't know as I can give you any reason for the selection of that runner. The plant was designed right after the war and has been in operation for about a year. I think, though, that efficiency was pretty important to them, and I believe that they were willing to pay the price for it.

The head at Chancy-Pougny varies from 21 feet at a flow of 42,400 c.f.s. to 32 feet at a flow of 4,240 c.f.s. The installation is for 43,000 h.p. drawing 15,500 c.f.s. It is a "run of river" plant with the power house and dam in a line. The dam is all spillway section, consisting of four openings of 39.5 feet width. Each of the five 8,700 h.p. vertical shaft Francis wheels has a runner diameter of 17 feet 7 inches, and passes 3,525 c.f.s. The generators are 7,000 k.v.a., 11,000 volts, 50 cycle, 83.3 r.p.m. Some of the turbines were built by the Atelier des Charmilles in Geneva, and some by Escher-Wyss in Zürich. Mr. H. E. Gruner of Bâle was the consulting engineer.

QUESTION: Has there been any trouble with erosion — pitting of the water wheels?

MR. HOUSTON: Assuming that the question refers to pitting in general, not at Chancy-Pougny in particular, I would say that there has been a good deal of pitting. In some places settling basins are utilized in order to get out the material that is in suspension. The wear on the turbine is materially decreased by having the water clean. Otherwise they always attempt to design the runner so as to have as little cavitation as possible. About all I can say is that they have a good deal of trouble there as here, and every one is striving to reduce it simply by correct hydraulic design, trying to so shape the blades as to eliminate it.

PROF. HAROLD K. BARROWS:* It is perhaps of interest to review the types of high-speed wheels designed and manufactured in this country. The ordinary reaction wheel reaches a specific speed of about

* Professor of Hydraulic Engineering, Massachusetts Institute of Technology, Cambridge; also Consulting Engineer, Boston, Mass.

110 as a maximum, as illustrated by the S. Morgan Smith type "U" wheel. The James Leffel & Co. now makes a wheel — their type "B," with a specific speed of about 148, constructed like a cut-away Francis or mixed flow wheel, but without a runner band or shroud.

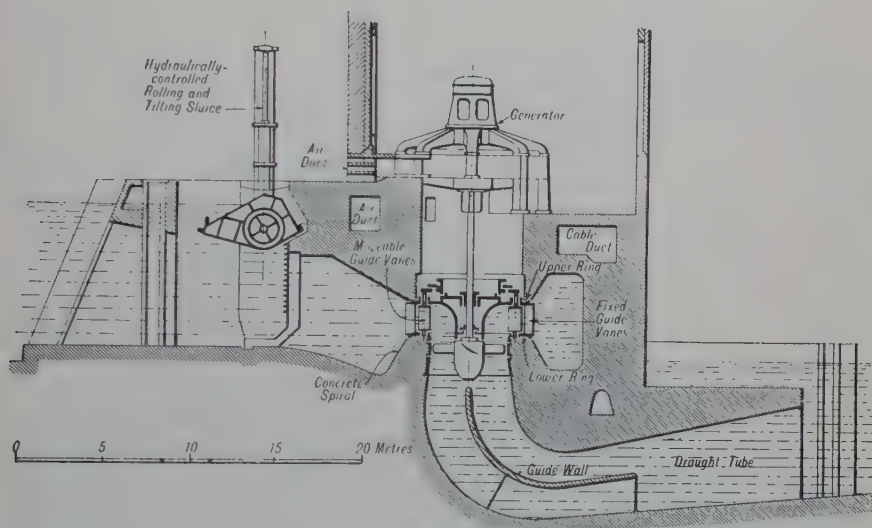


FIG. 24. — SECTION THROUGH THE KACHLET PLANT ON THE DANUBE
Six Kaplan turbines developing 7,500 h.p. at 75 r.p.m. under a head of 25.2 ft.

From: — The Engineer, Sept. 3, 1926

The propeller types of wheels include:

- (1) The Nagler type "N. X." of the Allis-Chalmers Company, with specific speeds ranging from about 140 to 175 or more.
- (2) The Moody diagonal runner of the I. P. Morris Dept. of Wm. Cramp & Sons, with a specific speed usually about 150.
- (3) The Bell type of S. Morgan Smith Company, invented and originally developed by the Theodore Bell Company of Switzerland, with specific speeds ranging from about 140 to 200.

The high speed or propeller type of wheel has the disadvantage of a rapid lowering of efficiency as the gate opening changes either way from the full load point (or gate of best efficiency). This disadvantage has been overcome by European manufacturers by the use of movable wheel blades. Perhaps Mr. Houston can tell us something of this device.

MR. HOUSTON: There is, of course, the Kaplan runner which is made by all the members of the Kaplan concern. There is an agreement by which a number of turbine manufacturers have the right to utilize his patents. There have been one or two installations by Escher Wyss in Canada. The hub is built very large, and inside there is an arrange-

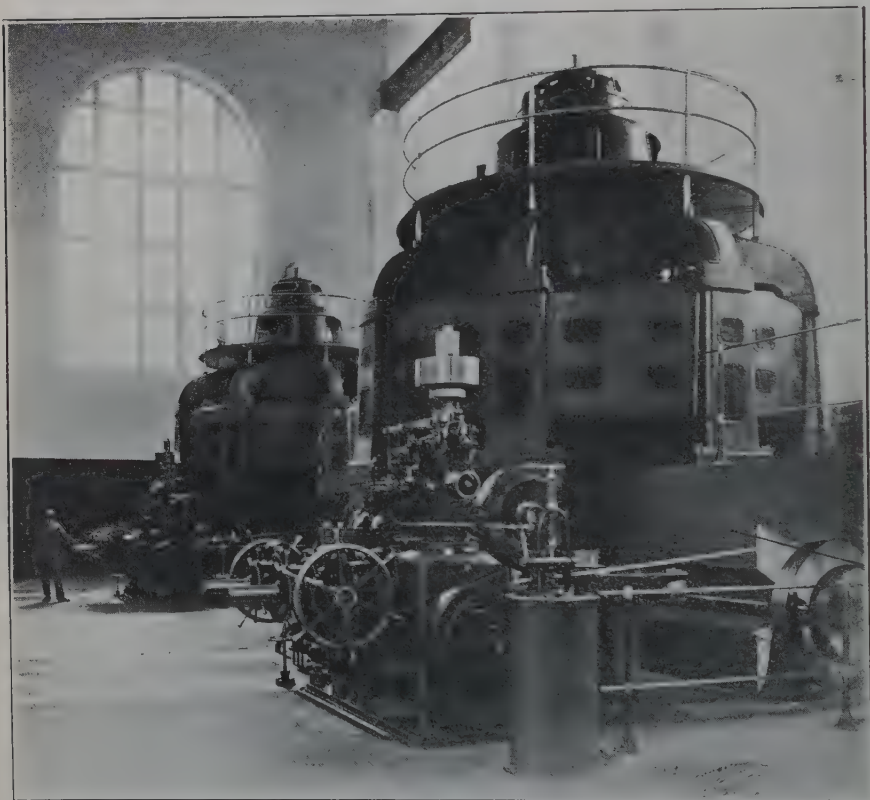


FIG. 25, — INTERIOR OF THE GRATWEIN PLANT NEAR VIENNA

Two Kaplan turbines developing 3,540 h.p. at 167 r.p.m. under a head of 28 ft.

Courtesy of J. M. Voith & Co., Heidenheim, Germany

ment for changing the angle of the blades. Regulation is generally effected by means of a ring which goes around the turbine shaft, or else by means of a hollow shaft. Sometimes a double governor is provided and the blades change their angle automatically according to the load or head. In some cases the blade angles are adjusted occasionally by hand, just as sometimes occurs with the needle nozzle of a small Pelton

wheel, when the load changes are taken care of by a deflector. Regulation of the blade angles not only improves the "part gate" efficiencies, but also aids in reducing cavitation and in adapting the unit to a variation in the head.

PROFESSOR BARROWS: For the discussion of Mr. Houston's interesting paper the speaker has prepared a few remarks on the amount and distribution of water power in the different countries of the world.

The water-power estimates of the United States Geological Survey, made in 1921 ("Water Power of the World"), although superseded in some countries by later information, furnish the best means available for a comparative study of water-power resources.

According to these estimates, *developed* water power totals about 23,000,000 h.p., of which about half is in North America and mostly in the United States. *Potential* water power totals about 439,000,000 h.p., of which about 43 per cent is in Africa, in regions where but little is likely to be used, the Congo River having in its basin alone about one fourth of the world's potential water power.

The total potential power noted is, however, the *minimum*, and corresponds approximately to the flow available 95 per cent of the time. If, therefore, all this water power were developed the wheel capacity would greatly exceed 439,000,000 h.p., perhaps two or three times this amount. Hence only about 2 per cent of the total available water power of the world has been developed as yet.

Aside from Africa, the potential water power is fairly evenly divided between the various continents, each with 10 to 15 per cent of the total.

Development of water power, especially in this country, is proceeding rapidly. During the past few years new developments averaging about three quarters of a million h.p. yearly have been constructed, — the greatest activity prevailing in the South and in the Pacific States. The present developed water power in the United States is about 11,000,000 h.p., — about 60 per cent east of the Mississippi River and mostly adjacent to the Atlantic coast. The great field for future water-power development is, however, in the West, — about 70 per cent of the potential water power being found in the Rocky Mountains and Pacific States.

In the table (Fig. 26) are data of comparative water-power resources for various selected countries and states. From this table it will be noted that Norway leads in *developed h.p. per 1,000 population* with 515 h.p., followed by Canada with 338 h.p. California, a little

Country or Subdivision	Population - Thousands	Area Thousand Sq. Mi.	Developed Water Power			Potential Water Power		
			Thousand HP.	HP. per 1000 pop.	HP. per sq. mi.	Thousand HP.	HP. per 1000 pop.	HP. per sq. mi.
Norway	2,646	125.	1350	515	11.	5,500	2080	44.
Canada	8,788	3730.	3000	338	0.8	18,000	2030	4.8
Switzerland	3,880	16.0	1070	280	67.	1,400	360	88.
Sweden	5,904	173.	1200	202	7.0	4,500	760	26.
United States	105,000	3027.	9000	85	3.0	34,000	324	11.6
France	39,403	213.	1400	36	6.6	4,700	120	22.
Italy	37,528	118.	1150	31	9.7	2,700	72	23.
Japan	56,960	149.	1000	18	6.7	4,000	70	27.
Germany	59,857	183.	1000	17	5.4	1,350	23	7.4
Liberia	1,500	40.	0	0	0	4,000	2670	100.
New Guinea	---	70.	0	0	0	5,000	--	71.
Europe	400,000	3879.	8877	22	2.3	45,000	112	11.6
Africa	180,000	11515.	1.1	0.0	0.0	190,000	1050	16.4
WORLD	1,700,000	52373.	23000	13	0.4	439,000	257	8.3
New York	10,385	49.2	1543	148	31.	4,010	386	82.
California	3,427	158.	1452	425	9.2	4,603	1340	29.
Washington	1,357	69.1	480	353	6.9	4,970	3670	72.
Oregon	783	96.7	207	264	2.2	3,665	4700	38.
New England	7,401	66.5	1387	188	21.	998	135	15.
Pacific States	5,567	324.8	2139	383	6.6	13,238	2400	41.

FIG. 26. — COMPARATIVE WATER-POWER RESOURCES OF THE WORLD

larger in area than Norway, has, however, 425 h.p. per 1,000, and in fact the Pacific States average 383 h.p.

Per square mile of area, Switzerland leads with 67 h.p., and far exceeds any other country in this respect. Of the divisions shown in the table, New York State is next with 31 h.p., followed by New England with 21 h.p. per square mile.

Potential water power per 1,000 population is greatest in Norway and Canada for the larger divisions, although the Pacific States far exceed in this respect. Liberia apparently ranks high, — subject, however, to the uncertainty of less accurate data.

On the basis of area, Switzerland is first for potential water power (excepting possibly Liberia), followed closely by New York State, which includes, however, power at Niagara and on the St. Lawrence River.

The foregoing comparative data must be regarded as only approximate, but they will perhaps serve to give a brief picture of the amount and distribution of water-power resources and its development.

C. H. PIERCE:* In his "Observations on European Water-Power Practice," Mr. Houston has given us some interesting illustrations of the art of hydro-electric development as practiced in several of the important countries of Europe. The advantages of extensive interconnection between systems and greater utilization of storage appear to be as clearly recognized there as they are here in the United States. It would be interesting if Mr. Houston could tell us something more in regard to the tendencies in European practice, that is, make comparisons between recent developments and those made prior to 1914.

In the United States the tendency appears to be toward the use of larger sized units, and correspondingly fewer in number for the individual power station. This may be due to the desire for economy, as under most conditions the development with the smallest number of units will have the lowest first cost, other things being equal. The use of the propeller type, which is now being installed for heads up to 50 feet, and some increase in the allowable speeds for Francis type turbines, have probably helped to promote this tendency.

An illustration of the somewhat radical differences in plant layout which have taken place during the past few years may be seen in the case of two developments on the Connecticut River. The Vernon Plant of the New England Power Company has ten units, aggregating about 42,000 h.p. The head is about 35 feet and the drainage area is 6,300 square miles. This plant was built in 1909 with eight units, the

* With Charles T. Main, Inc., Boston, Mass.

two additional units being added in 1921. The same company now has in progress a development at Bellows Falls, where, with a head of about 61 feet and a drainage area of 5,450 square miles, it is proposed to install three units aggregating 60,000 h.p.

For a rough comparison of these two developments, both on the Connecticut River and with similar conditions of stream flow, the head times the drainage area at Bellows Falls, divided by the head times the drainage area at Vernon, gives a ratio of 1.51. The turbine rating at Bellows Falls, divided by the turbine rating at Vernon, gives a ratio of 1.43. The ratio of drainage areas is 0.865 and the ratio of the number of units is 0.3. There is sufficient pondage for peak load operation of either plant, so that it would appear that the smaller number of units planned for in 1926, as compared with 1909, may be due to changes in ideas regarding the best method of hydro-electric development.

Another illustration of this change in ideas, or development in the art of hydro-electric construction, is afforded by the Spier Falls Plant of the Adirondack Power and Light Corporation. This plant was built about fifteen years ago, and was designed for ten 5,000 h.p. horizontal shaft units under a head of 80 feet. In 1924 alterations were begun with the intention of replacing four of the units, using 9,000 h.p., vertical shaft turbines. Three of the most efficient of the original units have been retained, giving a total of 51,000 h.p., an increase of 1,000 h.p., but with seven units instead of ten as originally planned.

Another tendency which may be observed in American practice is the increasing use of the automatic remote control station. A considerable number of small automatic stations have been built in Massachusetts and the other New England States during the past ten years, and recently some fairly large ones have been constructed. The most recent and the largest of these is the Sherman development of the New England Power System, now being built on the Deerfield River. This station is to have one 9,500 h.p. unit, under a 78-foot head, operated by long-distance (automatic) regulation from the Davis Bridge station, a distance of $2\frac{1}{2}$ miles. The same company now has a 6,000 h.p. unit at its Searsburg station, built in 1922, which is similarly operated, and the success of this installation is evident from the construction of the larger unit at Sherman.

The Holyoke Water Power Company now has a remote control station of about 4,300 h.p. which was increased to its present size in 1925 after four years' experience with a 750 h.p. unit of the same type.

Another large automatic station is the Sprite Creek Station of the Adirondack Power and Light Corporation, which develops 6,000 h.p.

under a net head of 370 feet. This unit is started and stopped by remote control from Ingram — a distance of 7.3 miles.

Unfortunately, most of our American power developments have little of the picturesque or beautiful to offer. Economy of construction and efficiency of operation are sought for, the architectural features

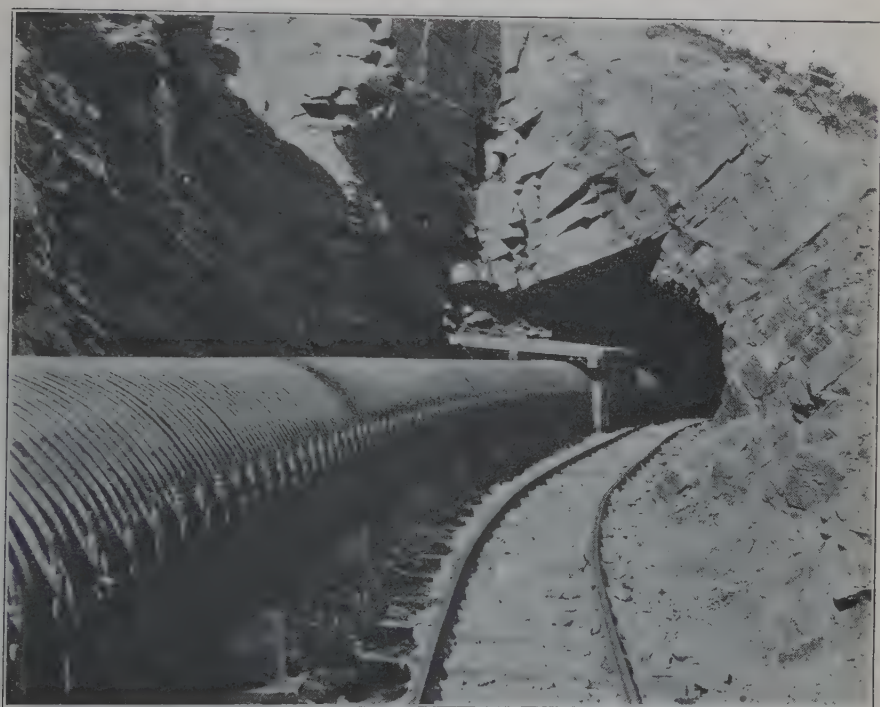


FIG. 27. — UPPER END OF 56-INCH WOOD STAVE PIPE

Showing granite dike which forms the barrier at outlet of Mystic Lake —
Montana Power Company

being often entirely overlooked. Indeed, it would be surprising if the management of an American power company should offer apology for the plainness of its structures. However, our developments are sometimes made under scenic conditions which rival those to be found in Switzerland.

The site of the Mystic Lake development of the Montana Power Company is located in the Beartooth National Forest Reservation in the south-central part of Montana. Prior to the construction of the

outlet dam the water surface elevation of Mystic Lake was 7,650 feet. The dam at the outlet raises the water 20 feet, to elevation 7,670. The lake is about half a mile wide and $2\frac{1}{4}$ miles long, and provides a storage of 20,500 acre-feet. The tributary drainage area is 50 square miles, from which the average run-off is 165 cubic feet per second. At the



FIG. 28. — JOHNSON SURGE TANK — 118 FEET HIGH
Upper end of pressure pipe — Mystic Lake Development
of the Montana Power Company

outlet there is a natural granite dike which resisted the glacial action which formed the lake.

The waters of the lake are tapped at El. 7610 by a tunnel about 6 x 7 feet in cross-section and 1,000 feet long, driven through the granite rock. From the outlet of the lake a 56-inch wood stave pipe about 9,000 feet long twists along the mountain side at a grade of 0.004, with curves having a minimum radius of 250 feet, and with 11 steel elbows

of 15 feet radius. At its termination there is a Johnson surge tank 118 feet high. The pressure pipe is of welded steel. It is 2,730 feet long and has a diameter of 48 inches at the upper end and 42 inches at the lower end, where it divides into two branches, each 28 inches in diameter and 111 feet long. The total operating head is 1,050 feet.

The power house is somewhat different in appearance from most of our power stations — at least to the extent that architects disagree



FIG. 29. — INTERIOR OF POWER HOUSE

Showing one of the two 7,500 h.p. units. — Mystic Lake Development
of the Montana Power Company

as to its artistic appearance, whereas regarding many power houses their verdict would be unanimous.

The roof is laid with Anaconda copper shingles.

Inside the power house are two 7,500 h.p. overhung impulse wheels carrying two 6,250 kva, 3-phase, 60-cycle, 6,600-volt, 300 r.p.m. generators, with step-up transformers to 50,000 volts, and the necessary auxiliary and electrical equipment.

This plant was designed and built under the supervision of Charles T. Main, in 1923-24. The general contractor was Winston Bros. of Minneapolis. The total cost was about \$115 a horse power.

While not remarkable for its size or general features, it is believed that this plant is representative of the better class of hydro-electric developments now being made in the United States, and this brief description is submitted for the purpose of comparison with European methods.

OF GENERAL INTEREST

PROGRESS ON DORCHESTER RAPID TRANSIT

Extension to Fields Corner will Probably be in Operation by Next Labor Day

The Dorchester Rapid Transit Extension is one of the most important developments in the improvement of passenger transportation facilities which has been undertaken in Metropolitan Boston. Col. Thomas F. Sullivan, the chairman of the Transit Department, City of Boston, has furnished our readers from time to time with information concerning this project. The following article details the awards of contracts for Sections Two and Three, a substation at Harrison Square, and the Columbia Station Entrance and Exit Building. In the January, 1925, issue Colonel Sullivan described the general scope of the project, and in the September, 1925, issue furnished data relative to the contracts for Section K of the Dorchester Tunnel and Section One of the Dorchester Rapid Transit Extension.

Proposals were received for the construction of Section Two of the Dorchester Rapid Transit on August 17, 1926, and the contract was awarded that day to A. G. Tomasello & Son, the lowest bidder. The ten bids received ranged from a maximum of \$272,410 to the bid of Tomasello, at \$255,910.

This work consists of the construction of a roadbed, together with station platforms, approaches and passageways for surface cars and buses, installing concrete floors on the present bridges, to-

gether with certain high-speed equipment, such as conduits for a double-track third-rail extension connecting with a similar extension now under construction at Harrison Square and extending to beyond Geneva Avenue, a distance of one-half mile in length. The work includes alteration and construction of bridges, retaining walls and foundations, concrete roadways, drainage systems, sewers, removal of buildings and re-grading.

In order to carry on this work promptly it was necessary to secure the removal of train service on the Shawmut Branch between Harrison Square and Shawmut Junction.

On August 31, 1926, eleven bidders submitted proposals for constructing Section Three of the Dorchester Rapid Transit, being the section from just south of Geneva Avenue to Peabody Square, Ashmont. It is about one mile in length, of which about 4,000 feet is to be covered, the tracks being depressed in order to abolish the existing grade crossings at Park Street, Melville Avenue, Mather Street, Centre Street and Welles Avenue.

This work consists of the construction of a typical subway section of steel and reinforced concrete, and includes a side platform station between Centre and Mather streets.

The principal items consist of the removal of 80,000 cubic yards of earth excavation, 5,000 cubic yards of rock excavation and the installation of 1,500 tons of structural steel and rods, with about 17,000 cubic yards of concrete. The contract was awarded to C. & R. Construction Company, the lowest bidder, at \$626,550. The maximum bid was \$1,069,400. The estimated time to complete this section is 300 days, and includes the rebuilding on wider lines of the existing wooden bridge at the junction of Dorchester Avenue and Talbot Avenue.

On October 5, thirteen bidders submitted proposals for building a substation at Harrison Square, which will be the first of several substations to be operated for the purpose of furnishing power for the Dorchester Extension. The contract was awarded to John P. Curley, the lowest bidder, at \$17,830, the work to be completed in three months.

On September 14, John P. Foley & Sons, the lowest bidder, was awarded a contract at \$43,929 for erecting Columbia Station Entrance and Exit Building, which will be the first station beyond Andrew Square of the Dorchester Rapid Transit Extension. The Columbia Station is located on Columbia Road at Mount Vernon Street.

Plans are being prepared for the station buildings at Savin Hill and Fields Corner, with a view to opening up the extension as far as Fields Corner by Labor Day next year.

Metropolitan Planning Division Activities

In addition to its general work, the Metropolitan Planning Division was instructed by the Legislature of 1926 to report on several special topics. These

reports are required to be submitted on or before December 1, 1926.

The most important of these will be the report on a comprehensive scheme for the extension and development of rapid transit service within the Metropolitan District, including the further correlation of steam and electric lines operating in the vicinity of Boston, and in connection therewith recommendations as to the methods of financing and operating the same.

It is easy to say that a rapid transit line should be extended in a certain direction or to reach certain points. The justification of such an extension is a matter to be proven by cold, hard facts, which will demonstrate the usefulness of increased facilities and the justification for the extensive expense involved.

The forthcoming report of the Planning Division will deal not only with the necessities for certain rapid transit extensions but will submit a financial plan for putting the same into effect, with a discussion of the economies effected by more efficient methods of handling the traffic.

Extensions of rapid transit usually entail a more or less extensive adjustment of existing service, whereby economies are effected which tend to justify what otherwise might appear to be too great an outlay. The subject matter of the forthcoming report has received much careful attention and study by the Division and its corps of engineers and experts.

Another special matter referred to the Division is the re-establishment of the harbor lines of the Charles River in the rear of the North Station of the Boston & Maine Railroad. Extensive improvements in the freight and passenger yards of this railroad at East Cambridge and Somerville are at present under way, according to plans already adopted. The future development of the passenger and terminal facilities will require a re-establishment and rebuilding of the North

Station and its appurtenances, and to do this effectively, changes in the harbor lines of the river are essential, not only to provide additional trackage for the passenger trains within the station, but as a measure of economy in substituting solid filling for the large areas of trestle construction now supporting a large portion of the passenger tracks entering the station.

The authorities of Medford are of the opinion that an additional bridge is required between the Wellington Bridge and Craddock Bridge over the Mystic River, and a special resolve of the Legislature requires the Division to investigate and report on such a project.

Among its general recommendations, the Division will have numerous suggestions for the improvement of the highway system of the Metropolitan District, not only in the line of extensive improvements, but also minor details in various localities which it is expected will aid materially in the convenience of the traveling public.

Boston & Maine Improves Freight Facilities at Boston

At the present time the Boston & Maine Railroad has under way terminal improvements, the basis of these improvements being the concentration of all freight houses and bulk delivery business now handled at four different freight yard locations — namely, East Cambridge, Minot Street, Warren Bridge and Rutherford Avenue, — at one central point.

After one year's careful study, East Cambridge was selected as the point for this freight house concentration, and on January 1 the first step toward same was made by discontinuing all freight business at Minot Street, Boston, and moving

the same into Houses 7 and 8 at East Cambridge. This concentrated all the Southern Division freight service at the one point.

The second step, that of bringing the Fitchburg Division freight business from Warren Bridge to East Cambridge, is now under way. This necessitates moving the Southern Division main line tracks now passing through East Cambridge to a new location at the south side of the so-called McLean Asylum hill; the reconstruction of the present yard No. 8 in Somerville, so as to provide for the quick handling and sorting of Southern Division freight; and the relocation of the present Fitchburg Division main line tracks on the north side of Millers River; and the reconstruction of freight yards Nos. 14 and 15, so as to provide for the entrance of the Fitchburg Division freight business.

To handle the additional freight in East Cambridge, rearrangements of tracks are being made and new freight house facilities being built near the present Prison Point Bridge. The plans provide for a two-story freight house 380 feet long and an additional section 200 feet long, one-half of which is now being built of concrete, six stories high, to provide for warehouse facilities. Two covered platforms approximately 600 feet long are to be built.

In order to provide bulk yard space, replacing that lost in building new freight houses, and also to cover space necessary on account of moving from Warren Bridge to East Cambridge, it is planned to build a bulk delivery yard in the area around East, Short, Water and North streets, where the city of Cambridge has been petitioned to vacate the streets. At this point it is planned to build a yard holding approximately 170 cars, and providing for automobile unloading service at the same time.

It is now planned to have these new facilities in service January 1, 1927, at

which time they can accommodate the bulk and freight house business now coming from the north and over the Southern Division and handled at Minot Street and East Cambridge, and all the business coming from the west over the Fitchburg, now handled at Warren Bridge.

The third step is that of complete concentration, which means bringing over the Portland Division business coming from the east and north and now handled at Rutherford Avenue and adjoining territory in Charlestown. In order to accommodate this service, plans are being made for an extension next year in the

Charles River, for which the last State Legislature passed an act changing the harbor line on the north side of the Charles River, and for which change the approval of the War Department is now being awaited.

With this approval and proper authority from the State it is planned to fill for additional bulk tracks and for an extension of 800 feet to the new freight house being built this year, as well as to the two covered platforms. This work will also require reconstruction of yards Nos. 9 and 10 on the Portland Division side of Washington Street.

PROCEEDINGS OF THE SOCIETY

MINUTES OF MEETINGS

BOSTON SOCIETY OF CIVIL ENGINEERS

MAY 19, 1926. — A regular meeting of the Boston Society of Civil Engineers was held this evening in Lorimer Hall, Tremont Temple, Boston, and was called to order by the President, C. M. Allen, at 7.20 P.M. There were about 100 members and guests present.

The minutes of the previous meeting (March 17, 1926) were approved as printed in the April JOURNAL.

The Secretary announced that the Board of Government had elected the following to membership:

April 21, 1926. *Members:* Walter H. Lee,* William H. Mueser,* Charles Terzaghi. *Juniors:* Leon R. Briggs, Charles A. Fitts, Erling A. Hanson, Arthur D. Martin, Herbert Albert Wilson.

May 19, 1926. *Members:* Alexander S. Addison, Wallace S. Carson, Stephen J. McNamara, Porter O. Robinson, Edward H. Thompson, Leon B. Turner, Louis H. Waters, Elmore L. Dearborn,* Joseph P. Furrier,* David C. Milne.* *Juniors:*

Robert C. Chapin, Israel Goldberg, Arthur N. Rae.

The President announced that Clarence T. Fernald, a member of the Society since March 21, 1900, had died on May 11, 1926. He stated that a committee would be appointed to prepare a memoir.

The President stated that the Board of Government had voted to omit the regular June meeting and to hold an outing on June 22 jointly with the New England Water Works Association, the outing to be held at the New Ocean House, Swampscott, the details of which are to appear in the June Bulletin of The Affiliated Technical Societies of Boston.

The President then introduced Edward P. Warner, Professor of Aeronautical Engineering, M. I. T., and head of the course in Aeronautical Engineering which has been recently established, who gave an interesting talk on "The Engineering of the Modern Airplane." Professor Warner presented a most interesting picture of the development of the airplane, stressing those points of design and construction of particular interest to the

*Transferred from grade of Junior.

civil engineer, and then told of the recent developments in commercial aviation both here and abroad.

After discussion, during which Professor Warner answered numerous questions, a rising vote of thanks was given to him for his courtesy in presenting this interesting paper.

Adjourned about 9.00 P.M.

J. B. BABCOCK, *Secretary*.

SEPTEMBER 22, 1926. A regular meeting of the Boston Society of Civil Engineers was held this evening in Chipman Hall, Tremont Temple, Boston, and was called to order by the President, Charles M. Allen, at 7.15 P.M. There were about 125 members and guests present.

The President stated that if there were no objections the minutes of the previous meeting (May 19, 1926) would stand approved as printed in the JOURNAL.

The Secretary reported for the Board of Government the names of those elected to membership:

June 16, 1926. *Members*: Charles O. Baird, William R. Butterfield, Joseph E. Cahill, Edmund J. MacDonald,* Edwin B. Murdough,* Robert B. Stephens, Jr., Henry M. Wilkins.*

September 22, 1926. *Members*: Henry B. Campbell, Richard L. Senior. *Juniors*: Nathan S. Brustin, Irving H. Call, Thomas G. Giblin, Joseph W. Kalinsky, Leroy S. Moulthrop.

The President announced the death of the following members: Desmond Fitzgerald, an Honorary Member and Past President of the Society, who died on September 22, 1926; David A. Hartwell, a Member of the Society since March 18, 1903, who died on August 3, 1926; and Willard C. Tannatt, Jr., a Member of the Society since April 2, 1909, who died on September 4, 1926.

The President announced that committees would be appointed to prepare memoirs.

The Secretary reported that the Board of Government had recommended to the Society that it pass the following vote:

That the Board of Government be authorized to use the income from the

Permanent Fund for the current year to such an extent as they deem necessary in payment of the current expenses of the Society.

Upon presentation of this matter to the Society, it was voted that this recommendation of the Board be adopted. (This matter will require final action at the next meeting.)

President Allen then introduced Mr. A. J. R. Houston (with Stone & Webster, Inc.), who gave an illustrated talk on "Some Observations on European Water-Power Practice." Following Mr. Houston's paper, Prof. H. K. Barrows showed some slides illustrating the distribution of developed and potential water power throughout the world. Mr. C. H. Pierce then spoke of some trends in American water-power practice and illustrated his talk with slides, showing typical water-power developments in this country. A general discussion followed, in which Mr. Houston elaborated certain points brought out in the discussion.

A vote of thanks was given to Mr. Houston for his courtesy in presenting this paper.

In view of the fact that the death of Mr. Desmond Fitzgerald had been announced at this meeting, Mr. John C. Chase spoke briefly on Mr. Fitzgerald's activities, with particular reference to his interest in the Society and the interesting lectures he had presented. Mr. Chase told of having recently met Mr. Randall L. Jones, Publicity Manager of the Union Pacific Railroad, who said that Mr. Fitzgerald had been about the first person to take photographs in Zion Park, Utah, and that it had been necessary for him to transport his camera seventy miles on mule back to get these photographs.

Meeting adjourned 9.15 P.M.

J. B. BABCOCK, *Secretary*.

DESIGNERS SECTION

MAY 12, 1926. — The regular May meeting of the Designers Section of the Boston Society of Civil Engineers was held in the Affiliation Rooms, and was called to order at 6.05 P.M. by the Chairman, Waldo F. Pike.

In the absence of the Clerk the Chairman appointed Kenneth C. Reynolds as Clerk *pro tem*.

The minutes of the April meeting were read and approved.

The Chairman introduced the speaker of the evening, Benjamin W. Guppy, Engineer of Structures, Boston & Maine Railroad. Mr. Guppy gave an interesting talk on "The Maintenance of Structures, including Inspection, Reports, Repairs and Records."

Mr. Lewis E. Moore also related some interesting experiences regarding the maintenance of bridges.

There were 31 members and visitors present. The meeting adjourned at 7.30 P.M.

KENNETH C. REYNOLDS, *Clerk pro tem*.

OCTOBER 13, 1926. — The regular October meeting of the Designers Section of the Boston Society of Civil Engineers was called to order at 6.08 P.M. in the Affiliation Rooms.

The reading of the minutes of the previous meeting was omitted.

The Chairman introduced Mr. Thomas H. Frost of the Physics Department of M. I. T., who talked on the "Photoelastic Method of Analysis of Stress Distribution." The talk was illustrated with numerous lantern slides.

There were 30 members and visitors present. The meeting adjourned at 7.15 P.M.

SCOTT KEITH, *Clerk*.

APPLICATIONS FOR MEMBERSHIP

[October 15, 1926]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the infor-

mation which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

For Admission

CHASE, LOUIS ABBOT, Winthrop, Mass. (Age 46, b. Malden, Mass.) From 1899-1912 with Aspinwall & Lincoln; 1912-19 with Massachusetts Land Court; 1919-22 with Aspinwall & Lincoln; 1920-26 (part time and full time), Registry of Deeds, Suffolk County; at present with Aspinwall & Lincoln. Refers to C. R. Berry, Channing Howard, C. B. Humphrey, W. J. Sullivan.

DAVIS, HERBERT GIBBS, Braintree Mass. (Age 18, b. Revere, Mass.) Entered Northeastern University in September, 1924. During work periods has been employed by E. W. Branch. Refers to H. B. Alvord, E. W. Branch, W. S. Carson, J. W. Ingalls.

DUWART, ROGER F., Gloucester, Mass. (Age 19, b. Gloucester, Mass.) At present a junior in Northeastern University. During work periods has been with the Essex County Engineer, Salem, Mass. Refers to C. O. Baird, C. S. Ell, R. R. Evans, J. W. Ingalls.

FOSTER, ROBERT STANDLEY, JR., Beverly, Mass. (Age 21, b. Beverly, Mass.) At present a student at Northeastern University. From April to September, 1925, was rodman for Essex County Engineering Department; from March to April, 1926, was rodman for Turner Construction Company; from April to September, 1926, with Massachusetts Department of Public Works, Division of Highways. Refers to W. J. Alcott, Jr., C. O. Baird, C. S. Ell, J. W. Ingalls.

GUERIN, FREDERIC WILLIAM, Worcester, Mass. (Age 27, b. Worcester, Mass.) Graduate of Mass. Inst. Tech., 1923. Draftsman, Norton Company, Engineering Department, Worcester, Mass.; assistant senior engineer, Massachusetts Department of Public Works, 1924 to present time. Refers to A. B. Appleton, W. G. Classon, R. W. Coburn, R. A. Vesper.

HARMAALA, JOHN ONNI, Gloucester, Mass. (Age 20, b. Gloucester, Mass.) Entered Northeastern University September, 1923. Employed as a rodman by Bradford & Weed, Lynn, from April to September, 1924; during sophomore year, during work periods, with R. R. Evans, and continuously by him from May, 1925, to June, 1926, as transitman, and occasionally chief of party. Now a Junior at Northeastern University. Refers to H. B. Alvord, C. O. Baird, C. S. Ell, R. R. Evans, J. W. Ingalls.

HOUSTON, ALBERT J. R., Boston, Mass. (Age 27, b. San Francisco, Cal.) Graduate of University of California, 1920; S.M. from Massachusetts Institute of Technology, 1922; special student in hydraulics, Eidg. Tech. Hochschule, Zurich, one year. From 1922-23 (six months) with Great Western Power Company; three months in 1924 tunnel driving in Switzerland; six months, same year, hydraulic turbine design, Zurich; and ten months in 1925, reinforced concrete design, Paris; since May 17, 1926, with Stone & Webster, Inc.; as draftsman. Refers to J. B. Babcock, H. K. Barrows, S. K. Cohen, H. A. Hageman, C. M. Spofford.

KILLAM, ALLISON LYNDY, Lynn, Mass. (Age 19, b. Lynn, Mass.) Entered Northeastern University in September, 1924, civil engineering course. During the school year 1925-26 co-operated with the firm of Bradford & Weed, Lynn. Refers to W. J. Alcott, Jr., H. B. Alvord, C. O. Baird, J. W. Ingalls, W. E. Nightingale.

KNOWLTON, CHARLES WILLIAM, Somerville, Mass. (Age 20, b. Somerville, Mass.) Enrolled at Northeastern University in January, 1925. Refers to H. B. Alvord, C. O. Baird, C. S. Ell, J. W. Ingalls.

LEUSSLER, JAMES A., Boston, Mass. (Age 20, b. Boston, Mass.) At present a Junior at Northeastern University; during work periods is with Aspinwall & Lincoln. Refers to H. B. Alvord, C. O. Baird, J. W. Ingalls, E. H. Lincoln.

PITMAN, WILLIAM HENRY, Salem, Mass. (Age 19, b. Salem, Mass.) At present a student at Northeastern University in civil engineering. During work periods has been with the city of Lynn, engineering department, and Aspinwall & Lincoln. Refers to H. B. Alvord, C. O. Baird, C. S. Ell, J. W. Ingalls, E. H. Lincoln.

POPKIN, JOSEPH D., Fall River, Mass. (Age 19, b. Fall River, Mass.) At present a student at Northeastern University. Refers to H. B. Alvord, C. O. Baird, C. S. Ell, J. W. Ingalls.

ROBERTS, ALBERT ARTHUR, Winchester, Mass. (Age 23, Wilmington, Mass.) At present a student at Northeastern University in civil engineering. During co-operative periods is employed by Henry F. Bryant, Brookline. Refers to C. O. Baird, H. F. Bryant, W. A. Bryant, J. W. Ingalls, G. W. Sawin.

SPOFFORD, FOSTER RAWSON, Berlin, Mass. (Age 20, b. Philipsburg, N. J.) At present a senior student at Tufts College in civil engineering. Refers to Robinson Abbott, H. P. Burden, P. P. Pasqualino, E. H. Wright.

WILBER, KARL HARRY, Brookline, Mass. (Age 23, b. Trenton, N. J.) June, 1920, to January, 1921, assistant to efficiency engineer, Du Pont Plant; February, 1921, to September, 1924, assistant to city engineer, South Amboy, N. J. Entered Northeastern University in September, 1924, and during work periods is assistant to city engineer, South Amboy, N. J. Refers to H. B. Alvord, C. O. Baird, E. L. Dearborn, C. S. Ell, J. W. Ingalls.

WINCH, NORMAN M., Framingham, Mass. (Age 20, b. Boston, Mass.) Entered Northeastern University, School of Engineering, September, 1924. During work periods has been employed by J. J. Van Valkenburg at Framingham. Refers to W. J. Alcott, Jr., H. B. Alvord, C. O. Baird, J. W. Ingalls, W. E. Nightingale, J. J. Van Valkenburg.

For Transfer from Junior.

FOX, VERNALD WADSWORTH, North Attleborough, Mass. (Age 26, b. Alton, Me.) Attended Northeastern University one school year and a summer course, and later transferred to Tufts Engineering School, where he attended half a school year, leaving on account of illness. From April to October, 1923, was employed by the Boston & Maine Railroad as structural draftsman and assistant on a bridge survey; with Stone & Webster, Inc., nearly a year. At present is transitman in Division of Highways, Massachusetts Department of Public Works. Refers to W. J. Alcott, Jr., J. B. Babcock, Pusey Jones, Anselmo Krigger, E. D. Mortenson, O. H. Tripp, Charles Weller.

NEW MEMBERS*Member*

RICHARD L. SENIOR, 73 Cloigui Avenue, New Rochelle, N. Y.

Junior

IRVING H. CALL, 229 Arlington Street, Wollaston, Mass.

DEATHS

DESMOND FITZGERALD . Sept. 22, 1926.
HENRY B. WOOD . . . Sept. 28, 1926.

BOOK REVIEW

"*Movable Bridges. Vol. I. Superstructure*," by Otis E. Hovey, Assistant Chief Engineer, American Bridge Company. 1st Edition, 1926. John Wiley & Sons, Inc., New York. 352 pages.*

This work, by the distinguished Assistant Chief Engineer of the American Bridge Company, will not disappoint those who have been waiting for it.

Besides treating the subject in the usual manner, a governing idea in the mind of

the author is suggested in the preface, where he says: "Few have discussed the special problems peculiar to the arrangement and design of the machinery. . . . One of the objects of the book is to collect and arrange the best of this material in convenient form for study and use, and to put the results of original investigations and the lessons learned from long experience before fellow engineers, in the hope of rendering a real service to the profession."

The author has accomplished this object. The book is a valuable contribution to the literature of the profession, and fills a gap which has long existed.

Chapter 1 gives a good historical review of movable bridges, from generally inaccessible sources. Chapter 2 classifies and describes the types of movable bridges, with excellent suggestions regarding the applicability of each type, and some statistics regarding cost and maintenance of some types. Chapter 3 describes the various forms of swing bridges, and gives formulæ and diagrams for weights. Chapter 4 does the same for bascule bridges, and gives a list of the patents on this form. Chapter 5 does the same for vertical lift bridges. Chapter 6 gives the well-known theory of continuous girders; and Chapter 7 gives its application to swing bridges. Chapter 8 treats of the analysis of bascule bridges. Chapter 9 contains an excellent discussion of the elastic deformations of beams and girders, for varying section, by several methods, and of the deflection of trusses. Chapter 10 treats of details of design, and contains valuable practical information regarding end lifts, camber, center bearings and discs. Chapter 11 deals with rail joints, Chapter 12 with counterweights, and Chapter 13 with operators' houses.

There is an interesting appendix on the stresses in discs, in which the author attempts to find the stress between two discs of slightly different radii when pressed together. There are solutions for this problem and for the stress between planes and rollers, but they disagree with each other and with experiment, and are

* Reviewed by George F. Swain, Gordon McKay, Professor of Civil Engineering, Harvard Engineering School; also Consulting Engineer, Cambridge, Mass.

unsatisfactory. The reader will have an opportunity to polish his wits in finding out whether the author has obtained a correct solution of this difficult problem.

There is also an appendix dealing with the treads of rolling lift bridges. Both these appendices are original.

The book contains a great deal of valuable practical information as well as theory, and should be in the hands of every engineer who is concerned with movable bridges.

It is not the purpose of this review to pick flaws, which exist in every human work. It may be suggested, however, that the reading of the book would be facilitated if the figures were not merely num-

bered, but if they had titles and more explanatory notes, where applicable. This is a minor matter which may be corrected in future editions if thought best. Altogether, the author and the publisher are to be congratulated on having produced a distinctly valuable addition to engineering literature.

It was originally intended that the author's work should appear in one volume. It has, however, been found desirable to divide it into two, of which this is the first. The second, which I understand will follow shortly, will contain fourteen chapters, dealing largely with the power, machinery, and materials used, with three appendices.

BOSTON SOCIETY OF CIVIL ENGINEERS

FOUNDED 1848

INDEX TO ADVERTISERS

	PAGE
ADAMS, H. S., 100-1 Ames Building, Boston	iii
ASPINWALL & LINCOLN, 46 Cornhill, Boston	iii
ASSOCIATED ARCHITECTS PRINTING & SUPPLY Co., 25 Pearl St., Boston	x
BARBOUR, FRANK A., Tremont Building, Boston	iv
BARROWS, H. K., 6 Beacon St., Boston	iii
BAY STATE DREDGING AND CONTRACTING Co., 62 Condor St., East Boston	x
BEATTIE, ROY H., 209 Bedford St., Fall River	ix
BERRY DRAFTING SERVICE, 101 Tremont St., Boston	iv
BISHOP, J. W., & Co., 683 Atlantic Ave., Boston	iv
BLAIR, ISAAC, & Co., INC., 433 Harrison Ave., Boston	xii
BOSTON INSULATED WIRE & CABLE Co., Dorchester	vi
BRUNO & PETITTI, CONTRACTORS, 18 Tremont St., Boston	iv
CLIFFORD & ROEBLAD, 101 Tremont St., Boston	iv
COLEMAN BROS., 245 State St., Boston	ix
CRANDALL ENGINEERING Co., 102 Border St., East Boston	xi
EASTERN BRIDGE AND STRUCTURAL Co., Worcester	viii
FAY, SPOFFORD & THORNDIKE, 44 School St., Boston	iii
FULLER & MCCLINTOCK, 170 Broadway, New York	iii
GIANT PORTLAND CEMENT Co., Philadelphia, Pa.	ix
GIBSON, RICHARD, & SON, 65 Long Wharf, Boston	ix
GOW COMPANY INC., 956 Park Square Building, Boston	vi
GRANITE PAVING BLOCK MFRS.' ASSOC., 31 State St., Boston	xiv
HOLZER, U., INC., 333 Washington St., Boston	vii
JACKSON & MORELAND, Park Square Building, Boston	iii
KEATING, P. J., COMPANY, 280 Main St., Fitchburg, Mass.	xii
MAIN, INC., CHAS. T., 201 Devonshire St., Boston	ii
METCALF & EDDY, 14 Beacon St., Boston	iii
MONKS & JOHNSON, 99 Chauncy St., Boston	iv
NEW ENGLAND FOUNDATION Co., INC., 120 Tremont St., Boston	ix
OLD CORNER BOOK STORE, 50 Bromfield St., Boston	ix
PALMER Co., INC., JOHN E., 1012 Old South Building, Boston	ix
PENNSYLVANIA CEMENT Co., 161 Devonshire St., Boston	viii
PORTLAND STONE WARE Co., 49 Federal St., Boston	v
RIEOUT, CHANDLER & JOYCE, 178 High St., Boston	ix
ROCKPORT GRANITE Co., Rockport	v
SCULLY Co., 238 Main St., Cambridge	vii
SIMPSON BROS. CORPN., 77 Summer St., Boston	v
SMITH, B. F., & Co., Merchants Bank Building, 79 Milk St., Boston	ix

	PAGE
STANDARD OIL CO. OF NEW YORK, 31 St. James Ave., Boston	xii
STONE & WEBSTER, INC., 147 Milk St., Boston	xiii
STUART, T., & SON CO., Newton, Mass.	xi
THOMPSON & LICHTNER, THE, CO., INC., 80 Federal St., Boston	iii
THORPE, LEWIS D., 6 Beacon St., Boston	iii
TUCKER, EDWARD A., CO., 101 Milk St., Boston	iv
WALDO BROTHERS AND BOND CO., 202 Southampton St., Boston	viii
WARREN FOUNDRY AND PIPE CO., 201 Devonshire St., Boston	vii
WESTON & SAMPSON, 14 Beacon St., Boston	iii
WHITMAN & HOWARD, 220 Devonshire St., Boston	iii
WORCESTER, J. R., & CO., 79 Milk St., Boston	iii
WRIGHT & POTTER PRINTING CO., 32 Derne St., Boston	x

A BUSINESS CARD in this Journal shows
*your interest in the Society and your
 appreciation of the patronage of its members*

PROFESSIONAL CARDS

CHAS. T. MAIN, INC.

ENGINEERS

201 DEVONSHIRE STREET
 BOSTON, MASS.

Industrial Building
 Textile Mills
 Hydro-electric Plants
 Steam Plants
 Reports and Investigations

Valuations for
 Accounting
 Taxation
 Insurance
 Purchase and Sale

H. S. ADAMS

Consulting Engineer

100-1 AMES BUILDING
BOSTON, MASS.

ASPINWALL & LINCOLN

Civil Engineers

46 CORNHILL
BOSTON

FAY, SPOFFORD & THORNDIKE

Consulting Engineers

Investigations Reports Designs
Engineering Supervision Valuations
Port Developments Industrial Plants
Bridges Buildings Foundations
Water and Sewerage Systems

44 SCHOOL STREET, BOSTON

FULLER & McCLINTOCK

Engineers

NEW YORK, 170 Broadway

PHILADELPHIA, PA., 1001 Chestnut St.
TOLEDO, OHIO, 352 Summit-Cherry Bldg.
KANSAS CITY, MO., 600 Walnut St.
WEST PALM BEACH, FLA., Room 2, Realty
Bldg., 115½ So. Poinsettia St.

H. K. BARROWS

Consulting Hydraulic Engineer

Water Power, Water Supply, Sewerage,
Drainage. Investigations, Reports, Valua-
tions, Designs, Supervision of Construction

6 BEACON ST. BOSTON, MASS.

METCALF & EDDY

HARRISON P. EDDY
CHARLES W. SHERMAN
ALMON L. FALES

FRANK A. MARSTON
JOHN P. WENTWORTH
HARRISON P. EDDY, JR.

CONSULTING ENGINEERS

Water Works, Sewerage Works, Industrial Wastes, Municipal
Refuse, Drainage, Flood Protection, Supervision of Construction and
Operation, Valuations, Laboratory for Chemical and Biological Analyses.
14 BEACON STREET BOSTON, MASS.

SANFORD E. THOMPSON, Pres. WILLIAM O. LICHTNER, Treas.
THE THOMPSON & LICHTNER CO., INC.

Engineers

Management and Production
Investigations
Design and Engineering Supervision
Testing of Structural Materials

Offices and Laboratory, 80 FEDERAL STREET, BOSTON

LEWIS D. THORPE

Civil and Sanitary Engineer

Water Works, Sewerage and Sewage
Disposal

Supervision of Construction and Operation

6 Beacon Street
BOSTON, MASS.

WESTON & SAMPSON

ROBERT SPURR WESTON G. A. SAMPSON

Laboratory for the Analysis of Water,
Sewage, Filtering Materials, etc., Design,
Inspection and Supervision of Water Puri-
fication and Sewage Disposal Plants.

14 BEACON STREET, BOSTON, MASS.

WHITMAN & HOWARD

Civil Engineers

(Established in 1869)

220 Devonshire Street Room 504
BOSTON

J. R. Worcester E. E. Pettoe G. H. Branson
MEMBERS OF AM. SOC. C. E.

J. R. WORCESTER & CO.

Consulting and Designing Engineers

Bridges Foundations
Steel and Reinforced Concrete Construction

79 MILK STREET, BOSTON

Cement Testing Laboratory at Waltham, Mass.

Dugald C. Jackson Edward L. Moreland

JACKSON & MORELAND

Consulting Engineers

PARK SQUARE BUILDING BOSTON, MASS.

Clifford & Roebled*Designing and Consulting
Architectural Engineers**Consulting Engineers on
Building & Structural Work*

101 Tremont St., Boston LIBerty 3263

MONKS & JOHNSON**ARCHITECTS—ENGINEERS****99 Chauncy Street****Boston****FRANK A. BARBOUR***Consulting Engineer**Water Supply, Water Purification
Sewerage and Sewage Disposal***Tremont Building, Boston, Mass.****EDWARD A. TUCKER COMPANY****Contracting Engineers****CONCRETE REINFORCEMENT
REMOVABLE METAL FORMS****101 Milk Street, Boston, Mass.****BERRY**
Drafting Service

101 TREMONT ST., BOSTON

LIBerty 2781

*Your Professional
Card**Would Look Well***IN THIS SPACE!****JOSEPH BRUNO****FRANK PETITTI****ALPHONSO BRUNO****BRUNO & PETITTI**
CONTRACTORS**WATERWORKS, SEWERS, HIGHWAYS AND
CONCRETE CONSTRUCTION****18 Tremont Street,****Boston, Mass.**NEW YORK
101 PARK AVENUEBOSTON
683 ATLANTIC AVENUE**J. W. BISHOP COMPANY**
GENERAL CONTRACTORSPROVIDENCE
617 BUTLER EXCHANGEWORCESTER
109 FOSTER STREET

Please mention the Journal when writing to Advertisers

SIMPSON BROS. CORPORATION



ENGINEERS AND CONTRACTORS
FOR

REINFORCED CONCRETE
CONSTRUCTION

HASSAM CONCRETE STREET PAVEMENT

PORTLAND STONE WARE CO.

MANUFACTURERS OF

SALT GLAZED SEWER PIPE, FLUE LINING,
LAND TILE, OIL FIRE BRICK,
BUILDING MATERIAL
PORTLAND CEMENT

49 FEDERAL STREET

FACTORIES
PORTLAND, ME.
PATTON, PA.

BOSTON, MASS.

YARD
CHARLESTOWN
MASS.

ROCKPORT GRANITE

RED GREEN GRAY

For Monumental Buildings, Bridges, Sea Walls
and Paving Blocks

It is an undeniable fact that chemical changes take place in the cement of CONCRETE construction exposed for any number of years to sea water, changes that are certainly not for the better.

No changes take place in Rockport Granite. It is permanent, and it is impermeable; and these FACTS are beyond question. The same facts apply to masonry work of every description—Rockport Granite is the ONE material of PERMANENCY.

A combination of Quality and Low Price is offered in Rockport Granite, full details of which will be supplied upon request. Write.

ROCKPORT GRANITE CO. - Rockport, Mass.
C. HARRY ROGERS, Treas. and Gen'l Mgr.

Branch Offices

Boston, New York City, Chicago, Detroit, Cleveland and Philadelphia

Boston Insulated Wire & Cable Co

SPECIFY **B.I.W.** WIRES

“HIGH GRADE”
GUARANTEED

“50% PARA”
GRADE

“REGULATION”
GRADE

MAIN OFFICE & FACTORY
DORCHESTER DISTRICT
BOSTON 25, MASS

CANADIAN FACTORY
BOSTON INSULATED WIRE
& CABLE CO., LTD.
HAMILTON, ONTARIO

FOUNDATIONS
ENGINEERS AND CONTRACTORS

The Gow Company Inc.
956 Park Sq. Building
Boston

GOW CAISSONS
RAYMOND CONCRETE PILES
SOIL TEST BORINGS

90 WEST ST., NEW YORK CITY 111 W. MONROE ST., CHICAGO

THE SCULLY COMPANY

Building Construction

238 MAIN STREET

CAMBRIDGE, MASS.

WARREN FOUNDRY and PIPE CO.

(FORMERLY WARREN FOUNDRY AND MACHINE COMPANY)

MANUFACTURERS OF

Cast Iron Gas and Water Pipe

FLANGE PIPE

SPECIAL CASTINGS

**201 Devonshire St.,
BOSTON, MASS.**

**SALES
OFFICES**

**11 Broadway,
NEW YORK**

U. HOLZER, Inc.

BOOK - BINDER

333 WASHINGTON ST., OPPOSITE MILK ST., OR 24 PROVINCE ST.

ESTABLISHED 1870

All kinds of Books bound and repaired.

Maps and Charts mounted.

Portfolios, Scrap Books, Blank Books, etc., made to order.

Lettering in Gold; Paper-Splitting; Inlaying; etc.

Photographs Mounted on Card or Paper without Cockling.

Main Shop

at

Hyde Park

Please mention the Journal when writing to Advertisers

EASTERN BRIDGE



— AND —



STRUCTURAL CO.

Worcester, Massachusetts,

For Prices on all Classes of

STEEL AND IRON WORK.

WE DESIGN AND MANUFACTURE

**ROOF TRUSSES, GIRDERS, COLUMNS, STAIRS
AND FIRE ESCAPES FOR BUILDINGS**

FOOT BRIDGES, HIGHWAY BRIDGES, RAILROAD BRIDGES

**We Carry a Large Stock of
I-BEAMS, PLATES AND ANGLES**

Can Make Quick Deliveries.   Send in Your Inquiries.

**THE EXTREME HIGH QUALITY OF
PENNSYLVANIA PORTLAND CEMENT**

**MAKES ITS USE ESSENTIAL WHERE
WORK OF THE HIGHEST CLASS IS DESIRED**

PENNSYLVANIA CEMENT CO.

NEW YORK OFFICE

131 East 46th St.

BOSTON OFFICE

161 Devonshire St.

WALDO BROS. AND BOND COMPANY

**Building Material and
Construction Equipment**

202 SOUTHAMPTON STREET, BOSTON, MASS.

Please mention the Journal when writing to Advertisers

How about
YOUR BUSINESS CARD
in this space?

GIANT PORTLAND CEMENT

A Standard Brand since 1883

RELIABILITY - - UNIFORMITY - - SERVICE

GIANT PORTLAND CEMENT CO

PHILADELPHIA NEW YORK BOSTON NORFOLK

"CONCRETE FOR PERMANENCE"

A SPACE THIS SIZE COSTS
 ONLY \$10.00 FOR A YEAR
 (TEN ISSUES).

RIDEOUT, CHANDLER & JOYCE

Engineers and Piping Contractors

178 HIGH STREET - BOSTON, MASS.

Steam Specialties, Engineers' Supplies
 Piping of All Kinds Furnished or Erected

ROY H. BEATTIE

Harbor Improvements
 Divers :: Lighters

209 BEDFORD STREET
 FALL RIVER, MASS.

SCIENTIFIC BOOKS AND PERIODICALS

THE OLD CORNER BOOK STORE
 50 Bromfield Street
 BOSTON, MASS.

JAMES R. GIBSON

RICHARD GIBSON & SON
BUILDING CONTRACTORS

MEMBERS
 MASTER BUILDERS' ASSOCIATION,
 BOSTON, MASS.

OFFICE: 65 LONG WHARF, BOSTON
 TEL: MAIN 3701

JOHN E. PALMER CO., INC.

JOHN E. PALMER

DANIEL S. BELL

JOHN A. STARR

CONTRACTING ENGINEERS

Contractors for Sewers, Water Works.
 Concrete Construction, Foundations,
 Roads, Landscape Work, Etc.

1012 OLD SOUTH BUILDING
 294 WASHINGTON ST., BOSTON, MASS.

B. F. SMITH & CO., INC.

ESTABLISHED 1878

Engineers and Contractors

ARTESIAN AND DRIVEN WELLS
 FOUNDATION BORINGS

79 MILK STREET
 BOSTON, MASS.

New England Foundation Co., Inc.

Engineering and Construction

Simplex Concrete Piles

Caissons — Difficult Foundations

120 TREMONT STREET BOSTON, MASS.

COLEMAN BROS., Inc.

JOHN F. COLEMAN, Pres. and Treas.

General Contractors and Builders

Main Office

245 STATE STREET, BOSTON

Brewer Building

CONGRESS 6886

Tracing Cloth Reproductions by Our Gelitho Process

We are its sole owners and producers.

BLUE, BLUELINE AND VANDYKE PRINTS
PHOTOSTAT PRINTS AND SUPPLIES

Associated Architects Printing and Supply Co.

25 PEARL STREET

BOSTON, MASS.

YOUR good is our good. We are here to serve **YOU**
Telephones LIBerty 1277 and 1278, connecting all departments



WRIGHT & POTTER PRINTING COMPANY

COMMERCIAL PRINTERS

32 Derne Street, - - Boston, Mass.

THIS entire building devoted to
all kinds of Book, Job and
Catalog Printing and Binding

Tel. Haymarket 2000 • 2001 • 2002

Bay State Dredging & Contracting Co.



CONTRACTORS

River and Harbor Improvements,
Sea Walls, Breakwaters, Heavy
Masonry Construction.

62 Condor Street, East Boston, Mass.

JAMES E. CASHMAN, Treas.

GORHAM H. WHITNEY, Prest.

DAVID J. WHITE, Gen. Mgr.

T. Stuart & Son Company

General Contractors



NEWTON, MASSACHUSETTS

THE CRANDALL ENGINEERING COMPANY

CONSULTING AND
CONSTRUCTING ENGINEERS

DESIGN of Floating, Basin, and Railway Dry Docks,
Wharves, Piers, Bridges, etc.

CONSTRUCTION of these and other Engineering
Structures

102 BORDER STREET
EAST BOSTON, MASS.

STANDARD REFINED MEXICAN ASPHALTS

(SOCONY Brands)

Furnished of required penetration and specifications for construction of Asphalt Macadam and Asphalt Concrete Roads, and for Sheet Asphalt, Asphalt Joint Filler and Bridge Asphalt.

Standard Macadam Asphalt Binder for penetration applied by SOCONY Asphalt Sprayers under pressure, at suitable temperature

QUOTATIONS AND SPECIFICATIONS FURNISHED ON REQUEST

STANDARD OIL CO. OF NEW YORK

NEW ENGLAND DEPARTMENT

Park Sq. Building, 31 St. James Ave., Boston, Mass.

P. J. KEATING COMPANY

General Contractors



Water Works, Sewers, Highways, Heavy Masonry
and Concrete Construction



280 MAIN STREET FITCHBURG, MASS.

GEO. A. BLAIR

L. L. STREET

W. O. WELLINGTON

ISAAC BLAIR & CO., Inc., General Contractors

Shoring and Moving Buildings a Specialty

433 Harrison Avenue, BOSTON



STONE & WEBSTER

Incorporated

DESIGN steam power stations, hydro-electric developments, transmission lines, city and interurban railways, gas and chemical plants, industrial plants, warehouses and buildings.

CONSTRUCT either from their own designs or from designs of other engineers or architects.

MANAGE public utility and industrial companies.

REPORT on going concerns, proposed extensions and new projects.

FINANCE industrial and public utility properties and conduct an investment banking business.

NEW YORK

BOSTON

CHICAGO

WHEN YOU DECIDE ON

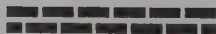
GRANITE

FOR

CURBING OR PAVING

YOU SETTLE THE PROBLEM

FOREVER



GRANITE PAVING BLOCK MANUFACTURERS'
ASSOCIATION OF THE U. S., INC,

31 STATE STREET, BOSTON

COMMITTEES

NOMINATING COMMITTEE

Past Presidents (Members of the Committee)

FRANK A. BARBOUR	ROBERT S. WESTON	DUGALD C. JACKSON
JOHN C. MOSES	EDGAR S. DORR	
EUGENE E. PETTEE	ARTHUR L. SHAW	
EDWARD WRIGHT	STURGIS H. THORNDIKE	
(Term expires March, 1927)	(Term expires March, 1928)	

SPECIAL COMMITTEES

Publication

WILLIAM D. HENDERSON, *Chairman*

JOHN B. BABCOCK, 3d	ARTHUR J. HARTY
J. STUART CRANDALL	FRANCIS H. KINGSBURY
GORDON M. FAIR	CHARLES H. PIERCE

Program

CHARLES M. ALLEN, *Chairman, ex officio*

JOHN B. BABCOCK, 3d	EDWARD P. HAMILTON
MILES N. CLAIR	BENJAMIN W. GUPPY
ROBERT R. EVANS	THEODORE B. PARKER
CARROLL A. FARWELL	ROBERT W. POND

Library

JOHN B. BABCOCK, 3d, *Chairman*

HOWARD A. GRAY	JAMES W. INGALLS
EVERETT N. HUTCHINS	RICHARD G. TYLER

Legislative Matters

RICHARD A. HALE, *Chairman*

JOHN N. FERGUSON	FRANK O. WHITNEY
------------------	------------------

Subsoils of Boston

HARRY E. SAWTELL, *Chairman*

HENRY S. ADAMS	HEYWOOD S. FRENCH
IRVING B. CROSBY	CHARLES D. KIRKPATRICK
ALBERT C. TITCOMB	

Social Activities

HUGH D. CHASE, *Chairman*

EDWARD S. AVERELL	GEORGE A. HASKINS
HENRY BRASK	HOWARD J. SPROTT
FRITZ F. HAMPE	BENJAMIN E. SULLIVAN
CHRISTOS HARMANTAS	CARL A. WOLFRUM
HARRY I. WYNER	

**LIBRARY AND MEETING PRIVILEGES ARE EXCHANGED WITH
THE FOLLOWING ORGANIZATIONS:**

- American Institute of Electrical Engineers, 33 West 39th Street, New York.
American Institute of Mining and Metallurgical Engineers, 29 West 39th Street, New York.
American Society of Civil Engineers, 33 West 39th Street, New York.
American Society of Mechanical Engineers, 29 West 39th Street, New York.
Brooklyn Engineers' Club, 117 Remsen Street, Brooklyn, N. Y.
Cleveland Engineering Society, Hotel Winton, Cleveland, Ohio.
Detroit Engineering Society, 478 Alexandrine Avenue West, Detroit, Mich.
Engineering Association of Nashville, Chamber of Commerce Building, Nashville, Tenn.
Engineering Institute of Canada, 176 Mansfield Street, Montreal, Canada.
Engineers Club of Baltimore, Bickford Building, 6 West Fayette Street, Baltimore, Md.
Engineers' Club of Dayton, cor. Monument Avenue and Jefferson Street, Dayton, Ohio.
Engineers' Club of Kansas City, Secretary's Office, Room 301, Dwight Building, Kansas City, Mo.
Engineers' Club of Philadelphia, 1317 Spruce Street, Philadelphia, Pa.
Engineers' Club of St. Louis, 3817 Olive Street, St. Louis, Mo.
Engineers' Club of Toronto, 96 King Street West, Toronto, Canada.
Engineers' Society of Pennsylvania, 31 South Front Street, Harrisburg, Pa.
Engineers' Society of Western Pennsylvania, William Penn Hotel, Pittsburgh, Pa.
Louisiana Engineering Society, State Museum Building, Jackson Square, New Orleans, La.
Montana Society of Engineers, Butte, Mont.
Rochester Engineering Society, Carnegie Building, University of Rochester, Rochester, N. Y.
Technology Club of Syracuse, 1158 Onondaga Hotel, Syracuse, N. Y.
Vermont Society of Engineers, Northfield, Vt.
Western Society of Engineers, 1735 Monadnock Block, Chicago, Ill.

THESE COURTESIES DO NOT INCLUDE CLUBHOUSE PRIVILEGES